DEVELOPMENT OF AN INTERNET OF THINGS(IoT)-BASED WATER MANAGEMENT SYSTEM

BY

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL & INFORMATION ENGINEERING, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE BACHELOR OF ENGINEERING DEGREE (ELECTRICAL ELECTRONICS ENGINEERING)

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AUGUST, 2021

DECLARATION

I hereby declare that I carried out the work reported in this project in the Department of Electrical Information Engineering, Covenant University, under the supervision of DR J.O OLOWOLENI. I also solemnly declare to the best of my knowledge that this report has not been submitted here or elsewhere for the award of a bachelor's degree. All sources of knowledge used have been duly acknowledged.

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(Signature & Date)

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CERTIFICATION

This is to certify that the project titled **DEVELOPMENT OF AN INTERNET OF THINGS(IoT)- BASED WATER MANAGEMENT SYSTEM** by OLUTOLA MOYINOLUWA, meets the requirements and regulations governing the award of the Bachelor of Engineering (Electrical Electronics Engineering) degree of Covenant University and is approved for its contribution to knowledge and literary presentation

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Name: Prof. Emmanuel. A. Adetiba Date:

Internal Examiner: Sign: ____________________ ________________________

Name:___________________ Date:

DEDICATION

From the commencement of my bachelor's degree program until the successful conclusion of it, this project work is dedicated to God Almighty, the Alpha, and Omega, for the strength, wisdom, direction, provision, and good health that have been bestowed upon me during the whole process. This report is also dedicated to my parents and siblings, whose unwavering support and encouragement served as a real source of inspiration in completing this report.

ACKNOWLEDGEMENT

I would like to express my appreciation to the Almighty, who made it possible for this project to be completed and for the reason for which it was completed. First and foremost, I want to express my gratitude to the Almighty, who made it possible to complete this project and the purpose for which it was done.

I am grateful to Bishop David Oyedepo, Chancellor of this magnificent school, for his reverence for Christ's leadership and for conceiving and promoting the idea of this great institution, Covenant University, where my destiny of royalty and dominion was realized. I also want to express my gratitude to Professor Abiodun Adebayo, the Vice-Chancellor, for his outstanding leadership. I owe a great deal to my project supervisor, Dr. J.O Olowoleni, for his unwavering supervision and the life skills and information I gained while working with him on this project. Without their comments, advice, and lessons learned, completing this report would have been challenging.

Finally, but certainly not least, I would like to express my appreciation to the teaching and non-teaching personnel of the Department of Electrical Information Engineering for their helpful ideas, advice, and direction. I must highlight the department's excellent working atmosphere and commitment to community involvement, which enabled me to accomplish a great lot.

ABSTRACT

Recent advancement of infrastructure, rise in population, uncontrolled usage of water, and pollution contributes to the water scarcity problem experienced by human beings. Furthermore, it is important to monitor the quality of water to prevent the consumption of low-quality water, which causes unfavorable health conditions to humans and is not suitable for plants. For contemporary society, ensuring a secure supply of portable water has grown into a significant problem to be overcome. Due to this issue, it has become essential to capture data in real-time rather than relying on traditional methods that involve collecting water samples, testing, and analyzing them in laboratories, which are expensive and time-consuming. These methods also do not allow for the rapid dissemination of information to relevant authorities to make timely and informed decisions. A new method based on IoT is suggested to fulfill the requirements for water, its distribution, and quality control (Internet of Things). The pH sensor is used for measuring water quality. This system is comprised of several sensors, including the pH sensor, turbidity sensor, and temperature sensor, all of which are interfaced with the Arduino Mega. The relay mechanism controls the solenoid valve to either continue or stop water flow from the above tank to the homes based on the data received by the sensors and analyzed by the microcontroller. The system allows users to monitor the parameters of the water and control the pump remotely and automatically.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Kevin Ashton, an IT professional, proposed the term "IoT" as a new term in 1999. This term has revolutionized the IT sector and has had profound effects on the technological world.. IoT enhances the energy efficiency, remote tracking, and control of physical assets and productivity through software as varied as home security to state monitoring in industries and factories. IoT is utilized in markets within healthcare, home appliances and buildings, retail markets, energy and production companies, mobility and transport, logistics companies, and media.

Technological equipment is becoming more digitized and much more linked, establishing networks between machines, individuals, and the world wide web, causing the creation of new ecosystems that allow higher productivity, better energy efficiency, and greater profitability. Sensors help recognize the state of things, by which they gain the advantage of anticipating human demands based on the information collected per circumstance. These intelligent devices collect information in their surroundings and can make decisions without human intervention. IoT technology is used within our day-to-day life for unlocking the door with no key; in card recognizers, automated home systems, automatic locks, vehicle detecting systems, toll payment systems, access management, payment systems, anti-theft apparatus, smartwatches, etc. The IoT building blocks will come from the ones that are web-enabled apparatus, supplying common platforms on which they can communicate and create new programs to capture new users.[1]

Thus, it is evident that the IoT links people to devices and devices to devices. All of these proceeds through the internet. IoT can also be applied in real-time monitoring. The Internet of Things (IoT), or the Internet of Things (IoT), requires cloud environments to transmit, store, and connect different devices. They may be linked through wireless networks that make use of the most recent wireless communication capabilities. Data gathering is enabled through the design of many types of sensors and devices. The data is then analyzed, allowing the computer to make choices based on previously set decision principles by the user in different programming languages.[2]. The data can be stored in a cloud, fetched, displayed on a web page or server, or an application designed to display the information.

1.1.1 Water Management System

Water is essential for survival in this world. Water is essential for the survival of many living things. Water quality is a critical factor in human health. It can also affect other species' environmental balance and cause serious health problems. Water scarcity is a growing concern due to the increase in water intake caused by the rapid growth of the human population. Apart from concerns regarding freshwater scarcity for drinking purposes, there is also increasing concern about water scarcity in agriculture. New methods for monitoring water quality in real-time are needed[3]. Effective water management is essential to address the problems of water scarcity. Water management relies heavily on real-time monitoring of water quality and level. Real-time water level monitoring may substantially decrease water waste caused by a tank overflow. Water management systems, which monitor water levels at various times, may identify water leaks in smart homes. The costly price of water control systems is one of the main reasons they are not widely used.

The cost of smart cities has fallen significantly over the past few decades due to the Internet of Things (IoT). The Internet of Things (IoT) has been gaining momentum for water control systems in the last two decades. The IoT ecosystem allows devices to transfer information without human interaction. This makes them perfect for monitoring real-time water levels. Smart cities have seen rapid growth in real-time monitoring of water quality [4].

1.1.2 Data in Water Management System

The water management system will be capturing various forms of data. They include pH value, conductivity turbidity, and the level of the water inside the tank. The various data are captured and collected using suitable sensors and processed using a microcontroller in this case which will be an Arduino, and they are transferred to the IoT platform, which can be stored in a cloud and monitored in real-time.

1.2 SIGNIFICANCE OF STUDY

It is common for refuse to be dumped into rivers and lakes. In Nigeria, high levels of metals and pesticides have been detected in the water. Underground water is also being polluted from sewage dump sites. This is a significant health hazard and results in the scarcity of fresh water in the country. Poor water quality, which is contaminated water, is the primary cause of typhoid fever, diarrhea, and dysentery in Nigeria. [5]. This results in the scarcity of fresh water in the country. This is why there is a need to monitor the water used by people, especially in the rural areas, and control the flow of water after the filtering has been done; entering and leaving the storage tanks.

1.3 PROBLEM STATEMENT

Due to the increasing casualties caused by water-related diseases, environmental pollution increases, especially in water. There is a need to design a system that monitors water parameters and control the submersible pump when certain conditions are met. In addition, this system will minimize water wastage by the users.

1.4 AIM AND OBJECTIVES

1.4.1 AIMS

This project aims to develop an internet of things (IoT)-based water management system that will serve to monitor water level consumption and monitor various water parameters.

1.4.2 OBJECTIVES

The objectives for the project are:

i) To design and implement a water management system

ii) Real-time monitoring of the water examining the pH value, turbidity, and flow rate when the pump is turned on.

iii) Automated and manual control of the submersible pump to prevent wastage of water.

iv) Access the information through a server over the internet

1.5 METHODOLOGY

The parameters collected by the smart management system, which are turbidity, pH, conductivity, and level of the tank, were obtained using their respective sensors. These sensors interface with the Arduino.

1.6 PROJECT SCOPE

This project mainly focuses on designing and constructing an IoT-based water management system that will effectively monitor various properties of the water and the water level in the tank. It will also control and monitor the inflow and outflow of water leaving the storage tanks.

1.7 LIMITATION OF STUDY

As no system can be 100% efficient, every system has its limitations. These are some limitations that come with the system.

i. Sensor errors can lead to inaccurate data.
ii. A network failure could result in users being unable to access required data for a certain period.
iii. Corrosion of metal parts of the components.
iv. Moisture in the tank could damage the sensors.
v. It is necessary to have an uninterrupted supply of electricity.

1.8 PROJECT ORGANIZATION

Chapter One: This chapter provides a summary of the project and the background information. It also explains the objectives and problems of the project.

Chapter Two: This chapter reviews the literature and discusses past works related to the project topic. It provides background information and other concepts that will help you understand the project.

Chapter Three: This chapter describes the project's approach, how it will be carried out, and the design. It contains all the design components, as well as block diagrams and software design.

Chapter Four: This chapter discusses the project's implementation and testing stages. This chapter will go through the functional system design in-depth and show real pictures of the project in use. This chapter will examine the project's outcomes.

Chapter Five: The report's findings and suggestions are included in the last chapter. It also shows the project's outcomes.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will be discussing and identifying essential information relevant and essential to water management systems. It also will be assessing the status and quality of the research related to past works. The research methods used in previous studies or papers will be evaluated and analyzed. This chapter will also present the sources' connections and group them into categories, concepts, and themes. It aims to identify the gaps in research that has been done in water management systems and draw conclusions and position the work within the existing literature

Applying IoT to our daily activities impacts human lives positively. From providing tools to manage diseases, providing information to the users in real-time about a particular product, offloading manual chores to programmed machines, and enjoying life resources in safer homes, rural areas, and cities. This study seeks to contribute to and explore a new solution to monitoring the water people drink based on the parameters provided and minimizes water wastage caused by humans.

2.2 DEFINITION OF KEY TERMS

i. **Water Management:** Water management is developing, managing, distributing water resources taking account of the quantity and quality to maximize and optimize the use of the resource

ii. **Sensors**: These are devices that detect and measure various physical phenomena such as temperature, pressure, sound, etc. Sensors can be classified based on power or energy supply requirements.

i) Active sensors: These are sensors that require a power supply. Examples include LiDAR, IMU, CCSDs

ii) Passive Sensors: These are sensors that measure and detect data from the physical environment. Examples include thermistors, temperature dependant resistors

A sensor's resolution is the minimum amount of change it can reliably detect. It is roughly the same size as the numeric value used to represent raw sensor readings.

iii. **Data Acquisition (DAQ)**: The act of monitoring real-world conditions and transforming them into digital values at fixed time intervals, the data sample rate, is known as data acquisition. Signal conditioning is also applied to filter usable data from the signal and scale raw sensor reading.

iv. **Actuators**: Actuators are output devices that convert an electrical signal into physical action. Examples are LEDs, speakers, screens, motors, solenoids. etc

v. **Real-time Monitoring**: Real-time monitoring is simply using tools and applications to track, monitor, and record a particular environment or object.

vi. **Embedded Systems**: An embedded system merges a microprocessor-based computer hardware system with software designed to carry or perform a specific function as an independent system or part of an extensive system.

vii. **Data Processing**: This is when data is converted to an easily understandable form to the user by the computer.

viii. **Water Quality:** Water quality refers to the chemical, physical, and biological properties of water that determine its suitability for a certain use.

2.3 REVIEW OF RELATED WORKS

A lot of research has been carried out, and it has shown the importance of encouraging the improvement of a smart monitoring and management system to monitor various parameters in our environment.

2.3.1 Review on Water Management Systems

Gupta investigated the wastage of drinkable water and the implications and introduced an IoT based Water Level Management system that monitors the consumption of water in multiple buildings with the use of an ultrasonic sensor placed on the storage tank, NodeMCU(ESP8266), and a relay to control the flow of the water. Furthermore, the system will also notify the users of the water usage and control water wastage.[5] Radhakrishnan discusses the need to have IoT architecture, including technologies that combine for the water distribution system. He also discusses the selection parameters for IoT water distribution and the benefits of IoT in intelligent drinking systems. He discussed IoT for water applications, including

i. Smart water system

ii. Smart Irrigation

iii. Smart Gardening

iv. Aquaculture System.[6]

M. Srihari recently published a research in which he utilized the internet of things to develop a water distribution and management system. The suggested system included a flow sensor, a control valve to guarantee equal distribution of water, a pH sensor to monitor water quality, and a pressure sensor to monitor water flow pressure and leak detection. The author's IoT module was an Ethernet shield, and the cloud computing service was MQTT[7].

Joshi et al. discussed the concept of smart villages and how it can enhance the quality standards of the village population. He also highlighted how the Internet of Things may be utilized to the subject of water management.. The title of the study was "Internet of Things Application for Water Conservation and Entrepreneurship in Rural Areas." With the use of IoT, the study offered answers to rural unemployment issues. They went on to discuss the basic needs for a water delivery system which consisted of

i. solar array panel,

ii. battery, flow sensor

iii. NRF (wireless transceiver module),

iv. turbidity sensors,

v. pH sensors,

The research presented the schematic layout for the water irrigation system, which includes solar array panels, batteries, flow sensor, moisture sensors, RTC, Solenoid valve, SIM800, ESP, and a temperature sensor. They concluded that IoT would improve living standards in rural areas and help control water wastage in rural areas.[8].

2.3.2 Review on Real-time monitoring systems

M. Santosh researched designing a water level monitoring and dam gate control over IoT to effectively monitor the quantity of water released by a dam and prevent water waste. It was designed using water level sensors placed in a dam to monitor the water, Raspberry Pi to process the data, and upload the water level status on a web server.[9]. The research conducted by Santosh encourages water conservation. It helps prevent floods in the areas around the dam, leading to the protection of lives and properties from danger. S.Kumar implemented IoT in designing an air quality monitoring system and tracks the following parameters: carbon monoxide, carbon dioxide, temperature, humidity, and pressure using various sensors and collected, processed, and transmitted using a low-cost ARM-based Raspberry Pi. The values of the parameters are then displayed on the IBM Bluemix Cloud.[10] Geetha developed the idea for a low-cost wireless water quality monitoring device with built-in wireless connectivity. pH, turbidity, conductivity, and turbidity were among the properties monitored by the system. The data collecting subsystem (data transmission subsystem) and the data management subsystem were the three major subsystems of the system. The TI CC3200, a single-chip controller with built-in Wi-Fi, was utilized in the system.[11]. Garcia et al. proposed a comprehensive survey of the usage of IoT devices in smart irrigation systems. It included a thorough examination of soil monitoring, weather monitoring, and irrigation sensor networks. Arduino boards have been found to be one of the most frequently utilized IoT devices for irrigation systems. The research provides a thorough assessment of IoT technologies and their maximum data rates.

Wi-Fi was determined to be the most often utilized communication technology in this research.[12]

Mani Dheeraj et al. proposed an IoT-based real-time energy monitoring system using a raspberry pi. In the proposed IoT-based energy monitoring system, existing industrial energy meters, Raspberry Pi, cloud (database, data web service, control application, and monitoring application), and visualization technologies were used. They used Node.js programming language with the raspberry Pi to collect data from the energy meters and store it locally. The system aimed to understand, monitor, and analyze daily energy patterns and facilitate energy conservation measures for reducing energy consumption. The author discussed the use of IoT in real-time monitoring compared to manual data collection and highlighted the significant advantages of using the technology.[13] Figure 2.1 presents a block diagram proposed by Mani Dheeraj representing an IoT-based real-time energy monitoring system.

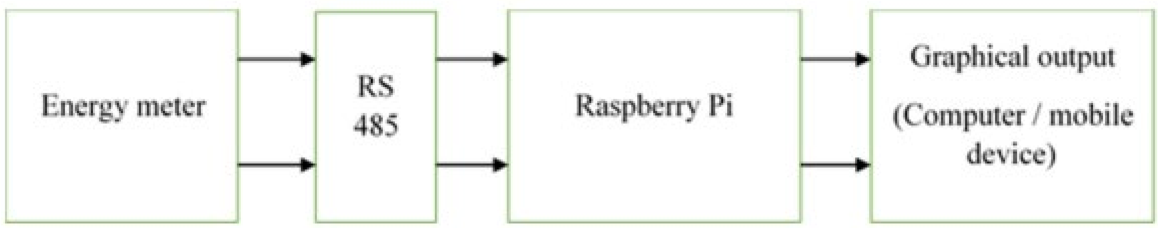

Figure 2.1: Block diagram of IoT based real-time energy monitoring system[13]

Vijayakumar researched "The real-time monitoring of water quality in IoT environment" to ensure a safe water supply. The proposed system is shown as a block diagram in Figure 2.2 below. The proposed system included a range of sensors for determining the physical and chemical properties of water, a Raspberry Pi B+ model, and an Internet of Things module. The sensor data could be displayed on the web using cloud computing. He further explained the suggested system's relation to the Internet of Things and a cloud computing method for displaying sensor readings via the internet.[14]

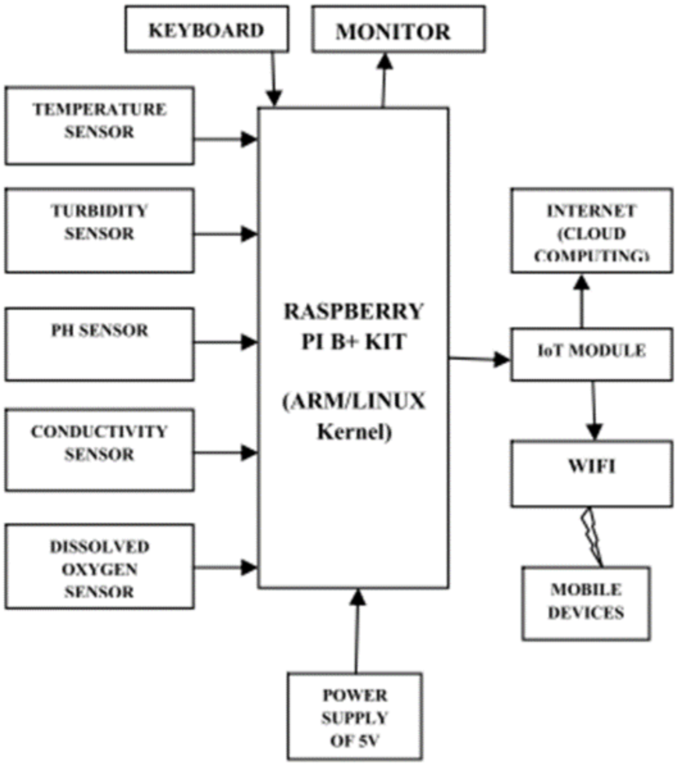

Figure 2.2: Hardware block diagram of water real-time monitoring system[32]

Hamid et al. discussed the adverse effects of swimming pool water pH levels on human skin, eyes, and eyes. They devised a smart water quality monitor system and evaluated factors that affect pH values and the temperature of the water using DOE-ANOVA statistical tools. The design consists of a NodeMCU V3, a processing unit, pH sensors, temperature sensors, and an IoT platform. Every five minutes, the sensors relay data to the processing unit, and the user gets a notification using telegram applications when the pH level changes. It will help the user monitor the swimming pool water temperature and pH value in real-time.[15] Wadekar et al. also presented an IoT management system that helps plan and monitor water usage in domestic and residential societies. The research paper proposed a solution for water management using IoT and discussed the need to handle the increasing water demand in urban and rural areas. The system consists of sensors wires that detect the water level, an ARM cortex M-4 microcontroller that uploads the water level to the cloud, and the software application that fetches data from the cloud and displays it to the user. Once the water level goes below a threshold value, the motor automatically turns on, and when the water goes above the set value, the motor turns off automatically.[16] Subramanya Chari et al. discussed an IoT-based flood monitoring and alerting system using a Raspberry pi. The article implements a model consisting mainly of water sensors and rain sensors to alert the authorities regarding the rain's severity and monitors water in ponds, lakes, and rivers. It also informs the people in the nearby villages using IoT. The proposed methodology involves using raspberry Pi with sensors to alert the government or the authorities to mitigate floods. The system consists of a Raspberry Pi, a rain sensor, and a water sensor.[17]. This system involves real-time monitoring of the weather and the intensity of the rain using rain sensors and water sensors. The system is a low-cost and flexible system that requires no real-time training.

Suresh et al introduced a liquid flow monitoring and control system using raspberry-pi that helps detect, monitor, and control various liquids' flow rates in industries through a web server. The flow meter measures the flow rate of the liquid, and the Arduino reads the pulses from the flow meter and transfers the data to the Raspberry Pi. The raspberry pi controls the electro valve, which is directly linked to the pipeline.

The liquid flow in the field could be monitored and controlled by using the internet through computers or smart devices.[18] Ajith Jerom et al. highlighted the significance of real-time water monitoring in India, as well as how it aids in the battle against environmental issues and improves health. They suggested a cloud-based IoT-based Smart water quality monitoring system. Real-time data collection, a communication interface, and a wireless sensor node are the three stages in the proposed system. They also devised a buoy system, shown in Figure 2.3, that comprises different sensors for measuring water characteristics such as seawater, temperature, salinity, water level, and dissolved oxygen. A database and data analyzer are used to process data and deliver signals to the user in the real-time data collection phase. A microcontroller with an IoT module for real-time monitoring makes up the communication interface. A wireless module, battery, and controller form the wireless sensor node. The sensors are embedded in the surface of the buoy to evaluate and monitor the water bodies.[19]

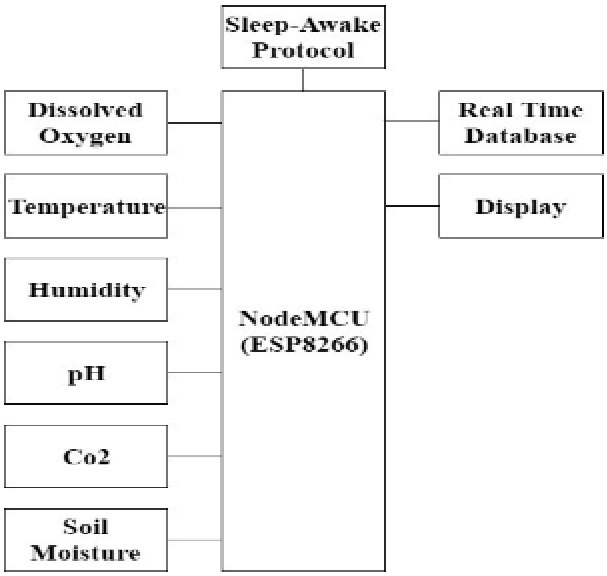

Figure 2.3: Block diagram of the buoy system[19]

2.3.3 Review on Water quality Systems

In this article, water flow and water quality are assessed by many parameters, such as pH, temperature, TDS, and turbidity. The tank level is monitored by means of level sensors and pressure flow-sensors are used to detect the leakage in the pipes. The author aim to construct a real-time leak detection system and an in-house leakage warning system for pipelines. Therefore, if a leak occurs, the cell phone is set up as an alert transmitter. [20]

Taking Nigeria as a case study, Water quality monitoring is really important in the rural areas due to the existence of contaminated rivers and lakes, which is the primary source of water for the rural communities. A recent study by J. Ighalo concluded that internet-enabled technologies commercially available were the best quality supply of drinking water in the nation. Internet-enabled technology should be utilized to check water quality. The author considered the traditional method of monitoring water to be inefficient and time-consuming[21]. R. Budarti provided a more extensive design and technique review for an automated water quality control system. The sensors were placed before the intake at the watergate, and data was extracted from the active sensor with python Serial Programming. It was then transmitted to the database via MQTT protocol.[22]. In recent research, Pujar et al. proposed an IoT-based system for real-time water quality monitoring. The pH, conductivity, and dissolved oxygen concentrations of Krishna river water were determined. Additionally, they included the temperature, biochemical oxygen demand, and total solids (TDS). The microcontroller was an Arduino Mega 2560. Furthermore, the research discovered that many elements have an effect on water quality at various periods of the year.[23] Danh et al. designed and deployed an E-Sensor AQUA platform to monitor water quality in the Mekong Delta. The system looked at the water's dissolved oxygen, pH, temperature, and salinity factor. The Thingspeak IoT platform was employed to save the data on the cloud server. The data from the sensor nodes are transferred to the central control unit, which updates the data every minute to the cloud server. To see the data, the system may be accessible using applications for both Android and iOS devices.[24] Wang et al. developed a system for monitoring the water quality in a river near Xinglin Bay in the Chinese city of Xiamen. The system is composed of three components: an analyzer for water quality, a data transmission system, and a computer system. Researchers used an online water quality tester to measure pH, dissolved oxygen (DO), conductivity, oxidation-reduction potential (ORP), chlorophyll, temperature, and salt. The data indicated that cycling river water was an efficient technique of ensuring the quality of river water. [25] Chowdury et al. have developed a sensor-based water quality monitoring system with a microprocessor for system processing, a communication system, and numerous sensors as its foundational pillars. To gather real-time data, he deployed IoT technologies and remote monitoring. With the support of streaming analysis through Spark MLlib and Deep learning neural network models, the data gathered at the river may be shown in a visual form on a computer. In addition, the suggested system contained a function that would send an SMS alert to the user if the acquired value surpassed the acceptable threshold value. Their objective was to design a water monitoring system with a high frequency, mobility, and low power consumption.[26] An IoT sensor-based drinking water quality measurement system was designed and presented to provide a cost-effective system and reduce the number of people contracting infectious diseases due to the water quality. The proposed system consisted of a DO (dissolved Oxygen sensor), pH sensor, GSM SIM 900 module, RTC module, and an Arduino Mega2560 as the microcontroller. The data gotten from the sensors would be sent through a wireless connection using a GSM SIM900 module to the database server at ThingsSpeak. Using an Android IoT application connected to the server, the data can be viewed.[27]. Pasika et al. provided a cost-effective water quality monitoring system using IoT. The equipment is capable of measuring the following parameters: the pH value of the water, the turbidity of the water, the water level in the tank, the temperature and humidity of the surrounding atmosphere. The suggested system utilized four sensors: pH, turbidity, ultrasonic, and DHT-11, as well as a microcontroller unit as the central processing module and an ESP8266 Wi-Fi module for data transmission. The Arduino Mega microcontroller is used to process the sensor's data and send it to the Thingspeak server via the Wi-Fi module.. The paper's purpose was to design a cost-effective system to monitor drinking water quality and minimize the deaths caused by drinking contaminated water.[28] Kshirsagar et al. created a water quality measuring system based on IoT. The article suggested the low-cost IoT idea and a mobile water quality and measuring system device. The system includes a pH sensor, conductivity and turbidity sensors that require signal conditioning using LMC 6001 IC. The signal obtained from the sensor is transmitted to the microcontroller that is configured for digital values analysis. Wi-Fi is connected to the microcontroller and the processed data is uploaded to a remote server.[29].

2.3.4 Other Related Works

V. Patchava demonstrated and developed the method for controlling household appliances using a Raspberry Pi microprocessor to get the current state of devices connected to the microcontroller. In the design of the author, he used software to obtain the state of the equipment and store it in the website database. It also indicates the device status on a monitor connected via HDMI.[30] Another research paper titled

Smart water level controlling system to control water wastage discussed freshwater scarcity and wastage of water in urban and rural areas. They presented a system that helps monitor the level of overhead tank water and informs the user to switch on and off the motor using a mobile phone. The system is made up of an Arduino board, an ethernet shield, a MySQL database server, a mobile app, a mobile phone, an overhead tank, and a sensor on the water level. The water level sensor is installed in the tank and connected to the Arduino, providing the microcontroller with information on the water level of the tank. The microcontroller updates the water level database via HTTP requests. The mobile phone finally displays the information stored on the server through a mobile interface.[31]

2.4 CONCLUSION

In this chapter, previous works on water management systems and real-time monitoring were discussed and reviewed. A precise overview of those topics was analyzed and examined to understand better the systems' methodology, processes, and overview. From the papers reviewed above, the importance of implanting a system to monitor and examine the level and quality of water is essential to minimize wastage of water and diseases. This present study will focus on improving water monitoring and management techniques.

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN

3.1 INTRODUCTION

This chapter discusses the process involved in the development of a water management system based on IoT. The various components required to build the hardware system are discussed. The schematics and the different components used are reviewed, and the vital circuit diagrams and block diagrams are shown where necessary. This chapter will discuss the methods and materials used in developing the project. The project involved measuring water cleanliness using a turbidity detector to measure light scattered rays from the water surface. A pH (power-of-hydrogen) sensor is also included in the design. It has a temperature sensor DS18B20 embedded onboard. This sensor can be used underwater to measure the pH of the water and the temperature of the solvent. The system also measures the water level of the container model and, if low, pumps water from the model tank while using its flowmeter to measure the fluid viscosity.

The project design methodology was based on components and part selection. The Arduino microcontroller was the brain of the design. Its cost and multifunction capabilities made it the ideal choice. The single-board computer collected sensor readings via UART communication protocol and then transferred that data to a Thingspeak dashboard using Python syntax.

3.2 HARDWARE REQUIRED

The hardware design was implemented using Arduino Mega. Arduino was selected to minimize cost and for the ability to download vast libraries. Table 3.1 shows the list of the various components that make up the hardware and their voltage ratings.

Table 3.1: Table showing the hardware components and voltage ratings

Electronic components	**Voltage specification (VDC)**
Arduino Development Board	5V
pH sensor	2.7V – 3.6V
Turbidity sensor	5V
Temperature sensor	1.5V – 5.5V
Ultrasonic sensor	3-5.5V

The block diagram shows the various sensors, which are pH, turbidity, temperature, ultrasonic sensor, and the flow meter to measure the flow rate. The microcontroller reads the analog sensors through serial communication. The Arduino also reads the pH value collected from the sensors and is programmed to perform some calculations on the data collected for accurate measurements.Figure 3.1 shows the block diagram of the system.

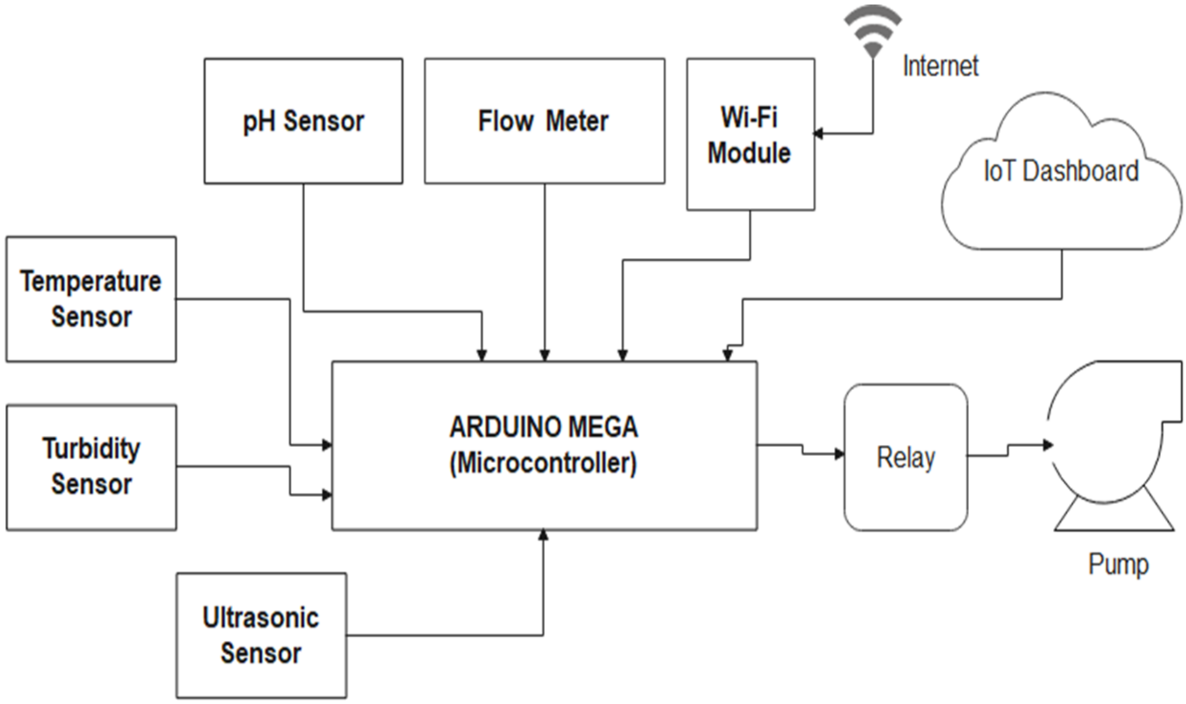

Figure 3.1: Hardware Block Diagram

3.2.1 Arduino Development Board

The Arduino micro board provides excellent flexibility and compartment. It is also a low-cost development board. The micro development board used is ATmega 328P which is an AVR family microcontroller. Table 3.2 below shows the technical specification as per the datasheet. Figure 3.2 shows the picture of the arduino board.

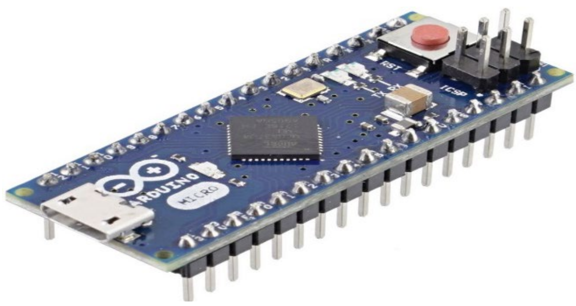

Figure 3.2: Arduino Board

Table 3.2: Table showing the hardware components and voltage ratings

TECHNICAL SPECIFICATIONS	
Operating Voltage	5V
Analog Input pins	6(A0-A5)
Digital I/O Pins	14
DC on I/O Pins	40mA
DC current on 3.3V pin	50mA
Flash Memory	32KB

3.2.2 pH Sensor

The pH sensor measures hydrogen ion activity within a liquid. A glass membrane covers the pH probe's tip. This allows hydrogen ions to diffuse into the outer glass layer while the larger ions remain in the solution. A minimal current is created by the difference in the hydrogen ions concentrations inside and outside the glass membrane. The concentration of hydrogen ions in the liquid is what determines the current. The solution is considered acid if the hydrogen ions in the glass membrane are lower than the hydrogen ions found outside. A base solution, on the other hand, is acceptable. Table 3.3 presents the technical specifiations of the pH sensor,

Table 3.3: Technical Specifications of the pH sensor

TECHNICAL SPECIFICATIONS	VALUES
Module Operating Voltage	5V
Module dimension	(43x 32) mm
pH Measuring range	(0 – 14) pH
Working temperature	(0 – 60) °C
Accuracy	± 0.1pH
Sensitivity	Gain Adjustment Potentiometer

Figure 3.3: pH sensor

3.2.3 Ultrasonic Sensor

The water level in a tank/reservoir is detected using an ultrasonic range sensor. Ultrasonic sensors are distance measuring devices that may be linked to a variety of available controllers. This sensor may be used to keep an eye on the amount of water in a tank.The water level sensor can help us determine if we have enough water. The sensor emits an ultrasonic pulse, and the return time is used to determine the distance to the target. The sensor emits an ultrasonic pulse of high frequency, usually in the 20 kHz-200 kHz range. After the echo is returned, the sensor listens for it. The cone transmits the pulse at 6 degrees from the apex. The Arduino microcontroller must determine the time it takes for the ultrasonic sound to travel to utilize this sensor to detect the level of the liquid. The following formula is used to calculate the distance the sound has traveled.

$$distance = \frac{time\ taken\ \times \frac{343m}{s}}{2} \tag{3.1}$$

Table 3.4: Technical specifications of the ultrasonic sensor

TECHNICAL SPECIFICATIONS	
Operating Voltage	3-5.5V
Working current	<2mA
Logic voltage	3.3V /5V
Induction angle	<15 °C
Accuracy	3mm
Detection range	2-400cm

Figure 3.4: View of an ultrasonic sensor

3.2.4 Esp8266 Wi-Fi Module

ESP8266 is a system on chip module whose function is for the enhancement and development of internet of things programmed applications. It consists of a 10-bit ADC (analog to digital converter) and has serial peripheral interface protocol capabilities. This is a cheap standalone wireless transceiver used for the development of IoT applications. The figure below shows the picture of an ESP 8266 Wi-fi module. This device consists of various pins which perform various functions. The following pins are enlisted in the Table 3.5 below.

Table 3.5: Table showing the module pins and their functions

Pins	**Description**
3V3	3.3V Power Pin
GND	Ground Pin
RST	Active Low Reset Pin
EN	Active High Enable Pin
TX	Serial Transmit Pin of UART
RX	Serial Receive Pin of UART
GPIO	General Purpose I/O Pins

Figure 3.5: ESP8266 Wi-Fi Module

3.2.5 Turbidity Sensor

Turbidity refers to the level of water cloudiness. To measure turbidity, optoelectronic devices like LDR or LED can be used. The sensors receive the reflected light from suspended solids. LDR stands for high resistance semiconductor. Semiconductor-absorbed photons may provide binding electrons sufficient energy to reach the conductive band if the light hits the device at a high frequency. The distance between LDR and LED in the proposed system is 9 cm. This allows for electricity to be conducted and lowers resistance.

This is a device that measures the clarity or muddiness utter in the water. Turbidity sensors detect how much light is dispersed in water by suspended particles. The water's turbidity (and cloudiness/haziness) rises as the total suspended solids (TSS) in water increases. The turbidity sensor detects suspended particles in water using light. The water is murkier due to the higher concentration of suspended particles. An IR LED and a photodiode are the components of the turbidity sensor. The IR LED emits light rays that are intended to reach the photodiode. These light rays travel through the water flow and scatter when they strike suspended particles in the water. The light that is received at the photodiode will be less than the light that was emitted. This difference in light received and sent is used to calculate the turbidity. Turbidity sensors can be used for stream and river gaging, wastewater/effluent measurements, control instrumentation, settling ponds, sediment transport research, and laboratory measurements. Figure 3.6 below shows the picture of a turbidity sensor.

Figure 3.6: Turbidity Sensor

3.2.6 Flowmeter

The sensor is composed of a plastic valve body and a rotor. A label at the top of the sensor contains vital information. The Flow Meter Sensor comprises a Flap Wheel or Turbine Wheel that spins as water flows through it. The center of the flap wheels has a fixed magnet. The Hall Effect IC used for this component was Honeywell's 460S Hall-effect Sensor IC. When the valve is turned on, water flows from the tank to the user through the pipe. The water flow sensor monitors both the rate of water flow and the presence of leaks. The water flow sensor is used to determine the rate of water flow. The water flow sensor is placed at a greater distance than the pipe to detect leakage. A longer distance leakage detection of a pipe is determined by the difference between the water flow rates 1 and 2. The difference in water flow rate must be zero to prevent water from leaking into the tube.Figure 3.7 below shows the turbidity sensor

$$Q = V \times t \tag{3.2}$$

Where Q is the flow rate, V is the volume, t is the elapsed time.

Figure 3.7: Flowmeter

3.2.7 Temperature Sensor

The Temperature Sensor is an electronic device that monitors temperature via an electrical signal. This signal is an electro voltage and is proportional to temperature.As the temperature varies, the voltage also varies. A temperature sensor monitors the object's temperature. The voltage across the diode is what determines the operation of a temperature sensor. Temperature change is directly proportional to the resistance of the diode. The resistance across the diode's diode is directly proportional to the temperature change. Displayed in numerical form over readout units. The DS18B20 temperature sensor measures degree of coldness and hotness using a 9-bit to 12 bit Celsius temperature measurement scale. The 4.7k resistor was used to program the sensor. It was connected between the data pin and the Vcc pin. It had non-volatile setoff points, which the user could program. It could be used in either normal power mode or parasite power mode. Normal power mode allowed the sensor to take Vcc from the Vcc rail, while parasite mode allowed it to take Vcc from the Data pin. This is possible because the temperature sensor communicates via a 1-wire bus. It requires only one data (and ground) line to communicate with a central microprocessor.

The temperature sensor used features a 64-bit serial number that allows multiple cascading of addressable sensors via 1-wire communication. A microprocessor can find them using these addressable codes. Figure 3.8 shows the picture of one-wire

Figure 3.8: One-Wire Temperature sensor

temperature sensor.

3.2.8 Power Supply board

This board converts 220V AC to 5V DC. The board consists of a transformer(to convert the 220V to 12V AC), a set of diodes for rectification, a capacitor for filtering, and a voltage regulator to convert the pulsating wave to a pure DC wave. This rail contains VCC and ground pinouts. It was used to transmit power to various sensors. 5V active HIGH is also provided to Collector pins of transistors in the relay driver module. The 1-Channel relay module would power the submersible pumps that supply water to the tank.

3.2.9 Submersible Pump

Submersible pumps (or submersible pumps, or electric submersible pumps are equipped with a watertight sealed motor that is tightly linked to the pump body. Once activated, these AC submersible pumps may be utilized to pump water into the tank. The whole mounting system is submerged in the pumping fluid. This pump avoids cavitation, which may occur when there are significant elevation variations between the pump's surface and the fluid. Submersible pumps transport fluid to the surface, as opposed to jet pumps, which generate a vacuum but rely on air pressure to operate. Submersibles are intended to run on hot water rather than heavy oil.. Figure 3.9 below is the diagram of a submersible pump

Figure 3.9: Submersible AC pump

3.2.10 Solid State Relay

A single channel relay can be powered by 5 volts of DC. It is a single-pole single-throw (SPST) type of mechanism. Once powered, it can energize its pole, and we switch to contact or non-contact mode. This 5V relay was used to activate the AC submersible pumps to pump water to the tank when it is low. It can also turn off the power supply to the submersible pumps when they are full. The DC relay is also a solid-state relay that makes it convenient to connect its Vcc pin directly to the actuator

PIN on the microcontroller, the NodeMCU microcontroller. Figure 3.10 shows the picture of the solid-state relay

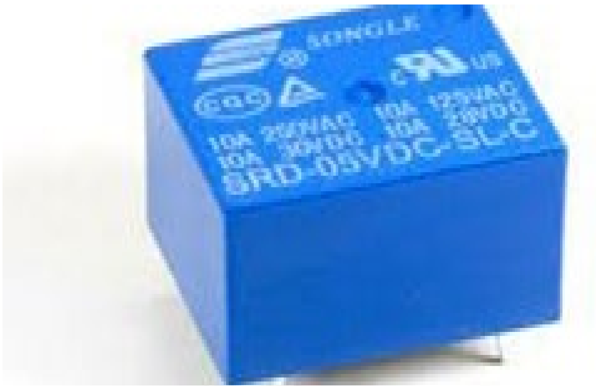

Figure 3.10: Solid State Relay

3.2.11 Jumper Wires

This electronic component is used to conduct DC in the power supply units (and other units). It was essential to avoid short-circuits and open circuits within the units. It also distributes the suitable voltages to all components used in the design. Figure 3.11 shows the pictoral representation of jumper wires.

Figure 3.11: Jumper Wires

3.3 SYSTEM SOFTWARE

Programming languages continue to develop as systems and programs change within an organization and research. Today, a vast range of programming languages, syntax, and functionality exist. C was used in this proposed system as the programming language to instruct the Arduino respectively to perform certain functions. The Arduino acted as the system's brain and was selected due to the ability to interface with analog sensors and other components, simplicity, cost, and utilizes less power to function. The Arduino also served as an ADC to interface between the analog values obtained and digital values. The cloud-based solution was applied to transmit data to the cloud server or data center for analysis. The text editor and IDE used was Arduino IDE.

3.3.1 Cayenne

Cayenne is an IoT project builder that may be utilized in a variety of IoT applications by developers, designers, engineers, and students. It simplifies and accelerates the IoT development process. It offers online applications that run in the cloud and mobile apps for Android and iOS devices. The dashboard is the primary graphical user interface for both web and mobile applications. MyDevices, an IoT Solutions business, invented the Cayenne IoT platform. myDevices was created in 2013 by Kevin Bromer, who also served as the company's CEO. The cayenne mobile apps could be used to regulate and manage physical equipment that is situated in different locations. The Cayenne dashboard has widgets that could be used to display data, define rules, set timers, and establish notification rules, among other things. The Cayenne platform can link many sensors, lights, motors, valves, relays, and generic actuators. It also works with different development boards such as the Arduino and the raspberry pi.

3.3.2 C++

C++ is a general programming language developed as an extension of the computer language C by Bjarne Stroustrup. The language has dramatically changed over time and the current C++ now includes object-oriented, generic, functional and cognitive functioning. C++ was developed with an emphasis on system programming, integrated, resource-restricted software and large systems, with efficiency, performance and flexibility as design goals. C++ has also proved to be beneficial in many scenarios, with two of its top characteristics being virtualized environments and resource restraining systems. This language is used in the Arduino IDE environment when uploading code to the Arduino micro development board. Figure 3.12 below shows the picture of the program on the Arduino IDE.

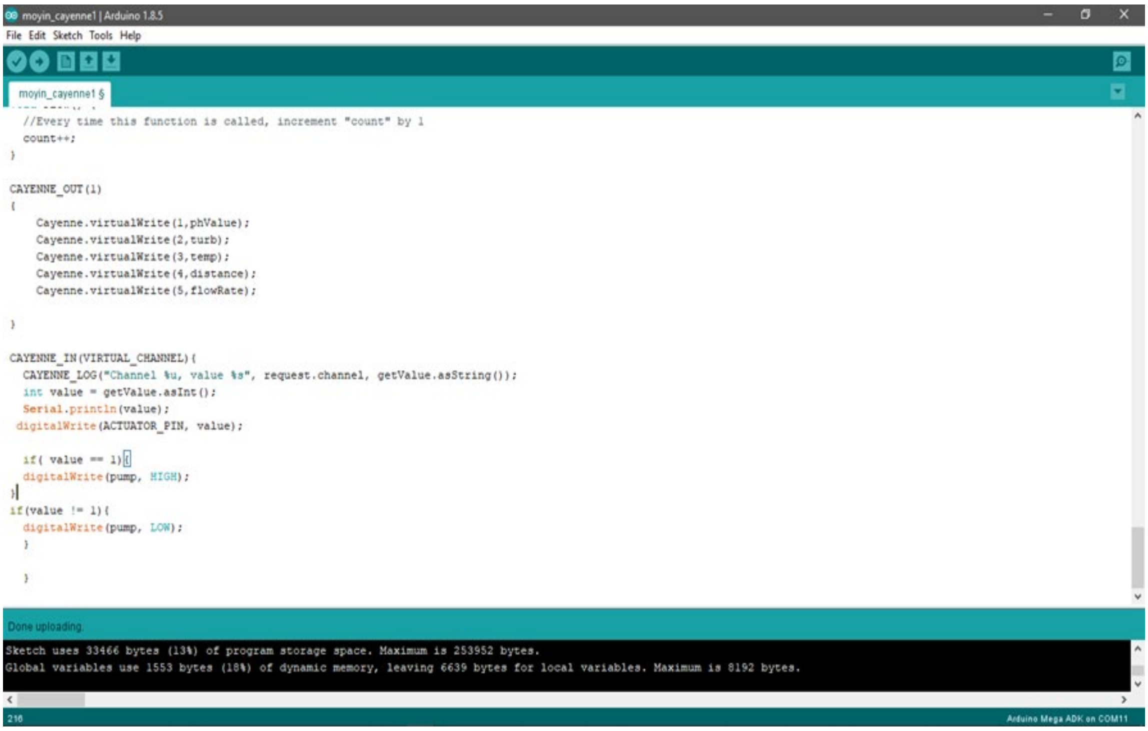

Figure 3.12: Sketch on Arduino IDE

3.4 METHODOLOGY

The water management system was constructed using soldering and the coupling of an active circuit. The soldering was done using a 40-watt soldering iron on the VERO Board.

The components were correctly arranged following the schematic diagram of the project.

3.4.1 Thinning

Thinning is the process of smoothing or scraping terminal components using a knife or sandpaper before and after soldering.

3.4.2 Soldering

Soldering is the process of using a soldering iron and soldering lead to connect conductors or component terminals to the circuit board. After the component's endpoints had been thinned, this procedure was carried out, and positive results were obtained from the component's testing.

3.4.3 Assembling of Components

The size of the VERO boards used will depend on the number of components. If necessary, you can allow for arrangements.

i. Start by placing components that need to be in a particular place first.

ii. Allow at least 100 millimeters between components and VERO Board edges.

iii. For consistency, space your components horizontally and vertically. Also, orient the circuit components in the same direction as possible.

iv. Assure that the orientations of polarized parts are the same.

v. Do not place your components at angles beyond 0 and 90 degrees

vi. If components must be on both sides of the printed circuit board, it is best to keep sensitive, heavy, or through-hole components on the primary side. Any components that require special attention should also be kept on this side.

vii. Trace lengths were minimized when deciding where components should be placed

3.4.4 Casing

A black plastic box was used to make the casing. It was large enough to hold the wiring and components. To test the design, the power supply plug was connected.

3.5 SYSTEM DESIGN

The system was designed, and the components were constructed and tested systematically. The datasheet of the sensors was considered to prevent over-voltage and high current damaging the sensors. Figure 3.13 below shows the schematic view of the water management system

3.5.1 Circuit Diagram

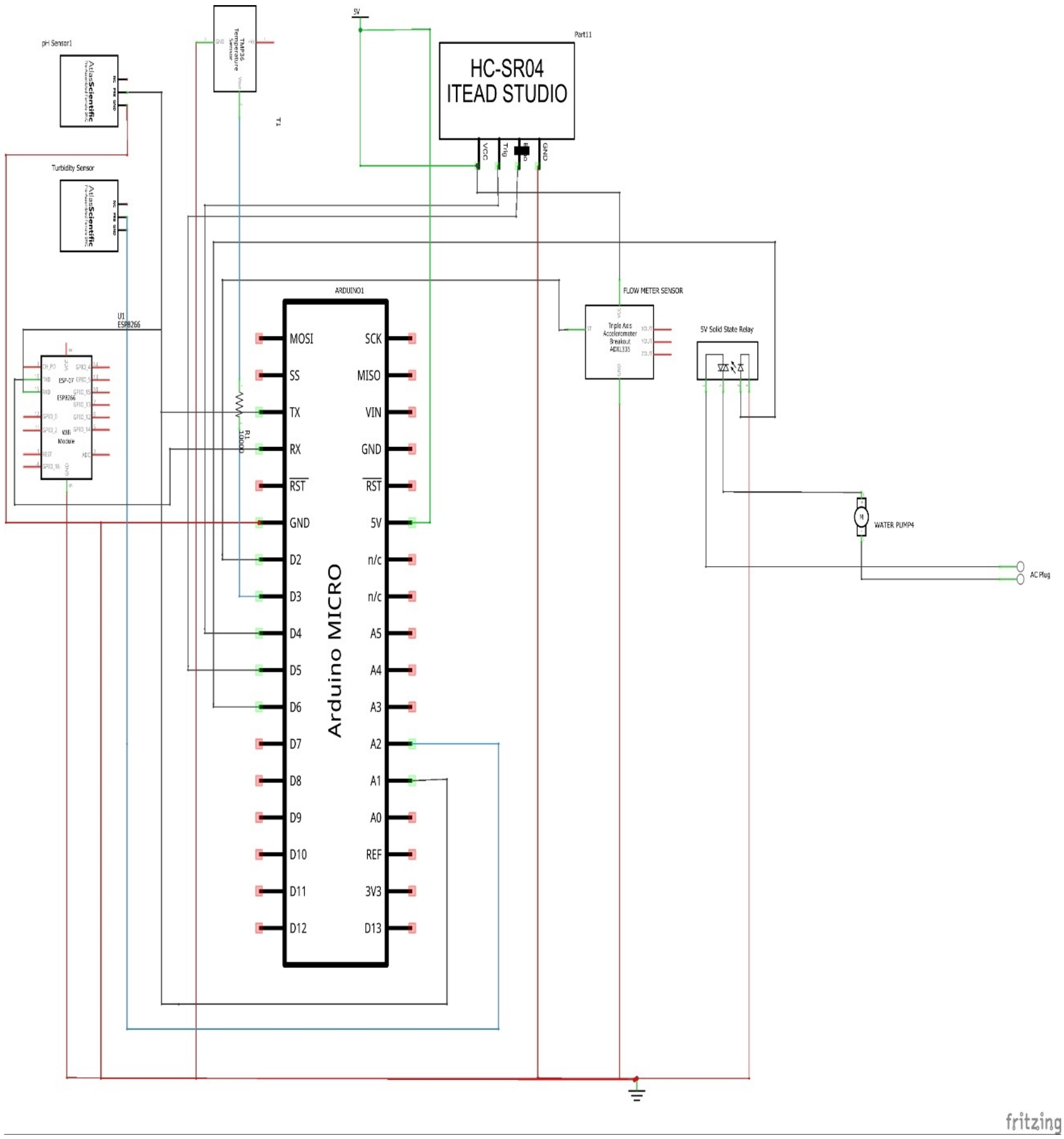

Figure 3.13: Schematic View on Fritzing

The circuit diagram above illustrates the several connections made between the sensors, the ESP8266 wireless module, and the Arduino. The Arduino mini and the ESP8266 Wi-Fi module's transmitter and reception pins are linked together. The temperature sensor is attached to an Arduino's digital pin (D3). The analog sensors, which include pH and turbidity sensors, are attached to the Arduino microdevelopment board's analog pins. The pH sensor is connected to the analog pin (A1).

Since the flow meter sensor uses hardware interrupt, It was connected to the interrupt pin of the Arduino micro development board, which is the digital in 2 (D2). The actuator pin, which is responsible for powering ON (HIGH) and OFF (LOW) the submersible pump, was connected to digital pin 6 (D6) on the Arduino micro development board.

To monitor and observe the level of the water in the model tank, a sonar sensor (HC-SR04) was utilized, and this the usage of two digital pins on the micro development board, as shown in the connection of the Digital pin 4 (D4) and Digital pin 5 (D5) respectively.

3.6 CONCLSUION

In this chapter, the materials used for the project and their specifications were reviewed and discussed. The methodology and the system design are also presented in this section and lastly, the hybrid diagram was represented and shown in this chapter.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 INTRODUCTION

This chapter summarizes the work accomplished during the project's development. Every process or block that forms the system and its materials is tested for its performance. This chapter describes the work carried out in different parts of the project and the various steps involved in completing the project. After the conclusion, the components were packaged in a box for presentability. This chapter is the most practical section of the project.

4.2 CONNECTING THE SENSORS

The designed system comprises a number of sensors coupled to the Arduino's digital and analog ports. The turbidity sensor was linked to analog pin A2, which translates the sensor's voltage to integers between 0 and 1023. The Arduino has a 10-bit resolution. The ultrasonic sensor was connected directly to digital pin 5 of the microcontroller (D5). The pH sensor was attached to analog pin 1 (A1), which converts input voltages ranging from 0 to 5 to integer readings. The flow meter is connected to the digital pin two and programmed to calculate the flow rate of the liquid.

4.3 PACKAGING

The project components were connected to the Arduino micro development board and the ESP8266 Wi-Fi module and packaged in a box that is attached to the container. Figure 4.1 and 4.2 below shows the internal connections and the general overview of the prototype.

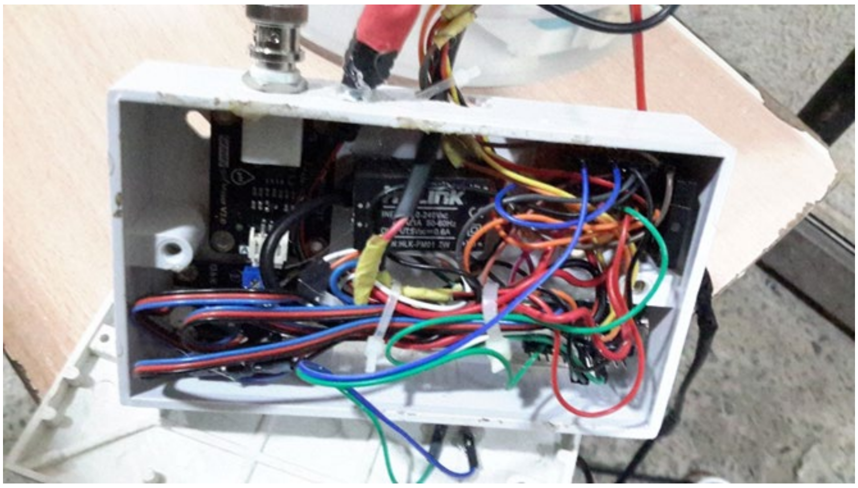

Figure 4.1: Internal connection of the hardware components

Figure 4.2: Overview of the prototype

4.4 TEST RESULTS

Arduino does the function of collecting all these analog data from the sensors, processes and analyzes the data, and sends it to the Cayenne dashboard using the

ESP8266 Wi-Fi module. Covenant university water was used to test the prototype. Water was first poured into the storage reservoir. Once the level of the water passes a certain level, the submersible pump pumps the water inside the reservoir into the storage tank. Futhermore, the sensors monitor the water's characteristics, including temperature, pH measurement, turbidity, and level. The system notifies the user's email whenever the water is unsuitable for consumption, or the tank is almost empty or full.

4.4.1 DASHBOARD

The various sensor values are shown in the dashboard on Cayenne Dashboard. The channel fields are temperature, pH reading, turbidity, flow rate, water level. Some widgets are also included in the dashboard, and mails are being sent to the user in different scenarios, especially when the water is not suitable for consumption and to check the water level and avoid wastage. The following figures 4.3,4.4,4.5 below are what the dashboard displayed after different tests had been carried out.

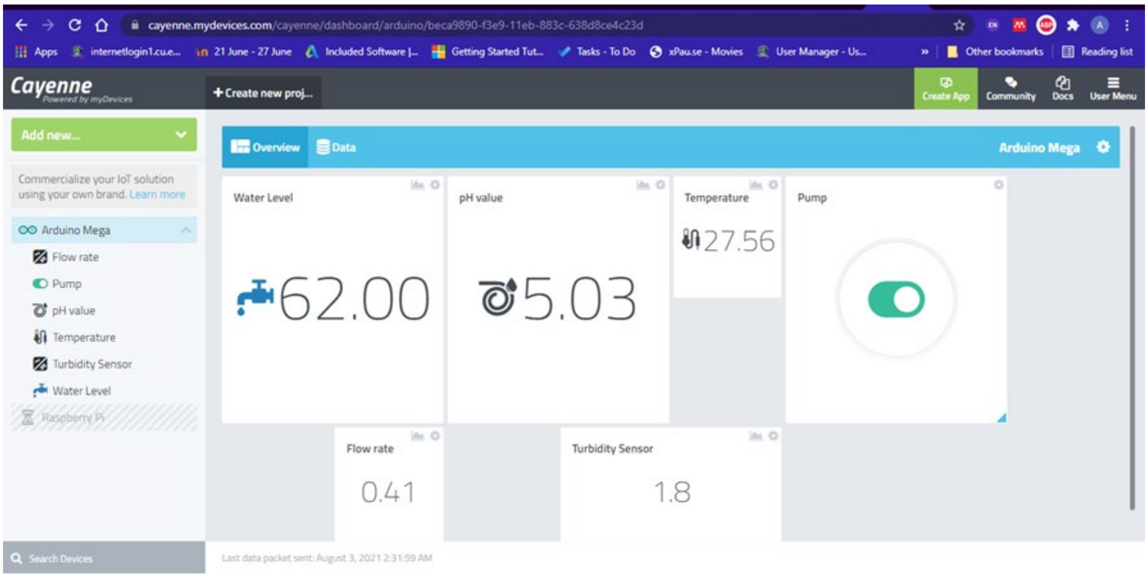

Figure 4.3: Cayenne Dashboard showing the results

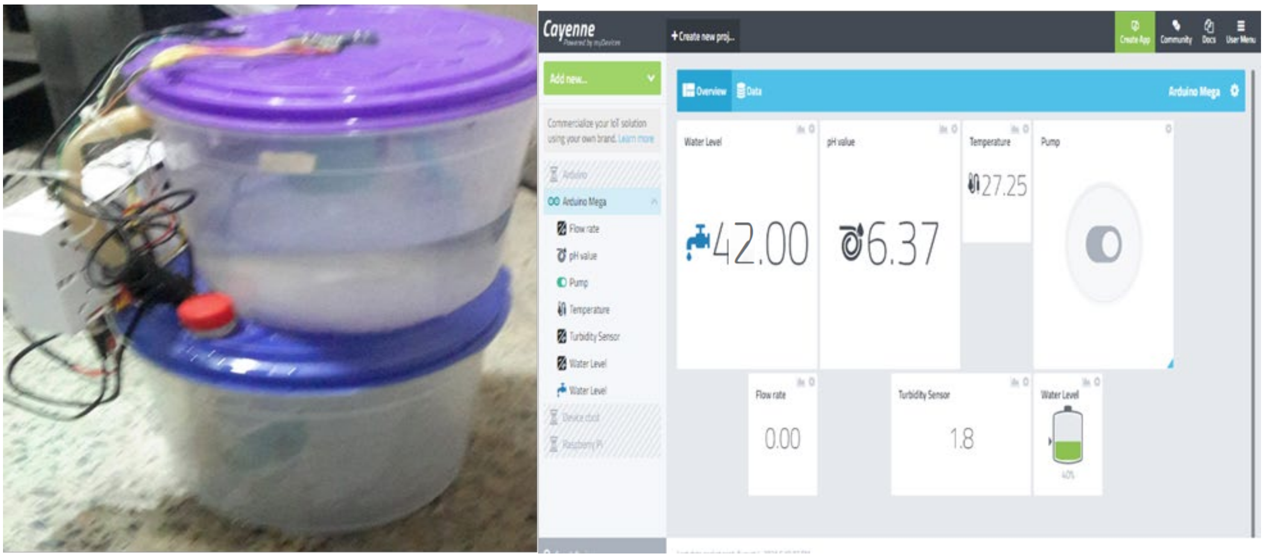

Figure 4.4 Test conducted on the clean water sample

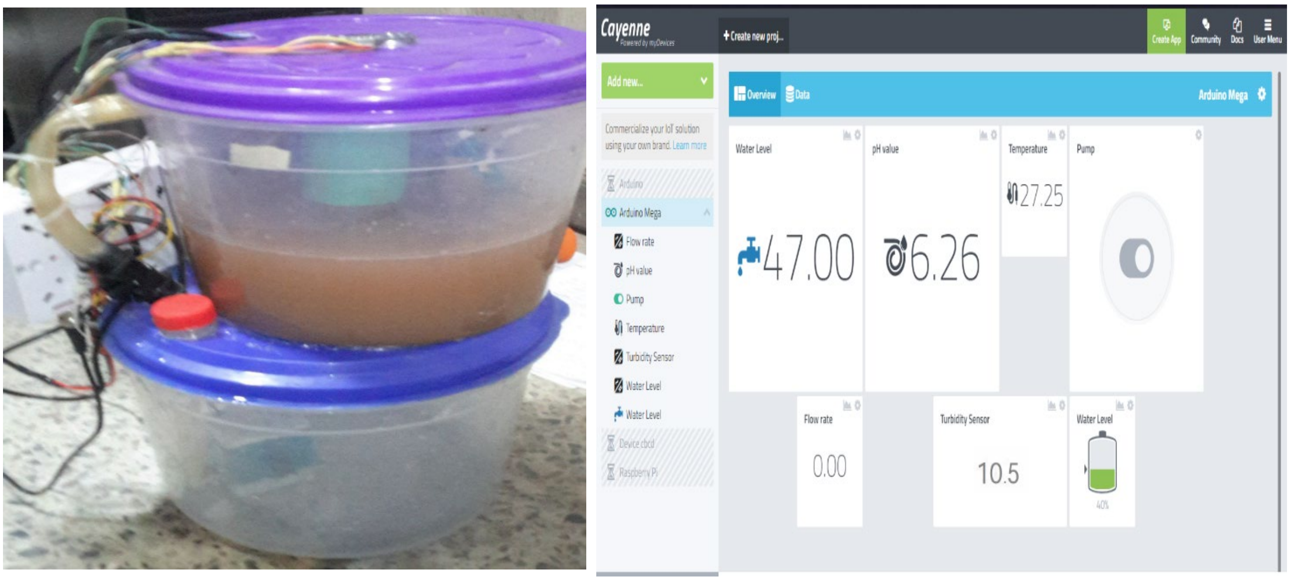

Figure 4.5 Test conducted on Unclean water and the results

Mud was put inside the tank in Figure 4.5, which made the particles brown and opaque, and the turbidity measured the value of the water as 10.5 NTU, which is not suitable for consumption

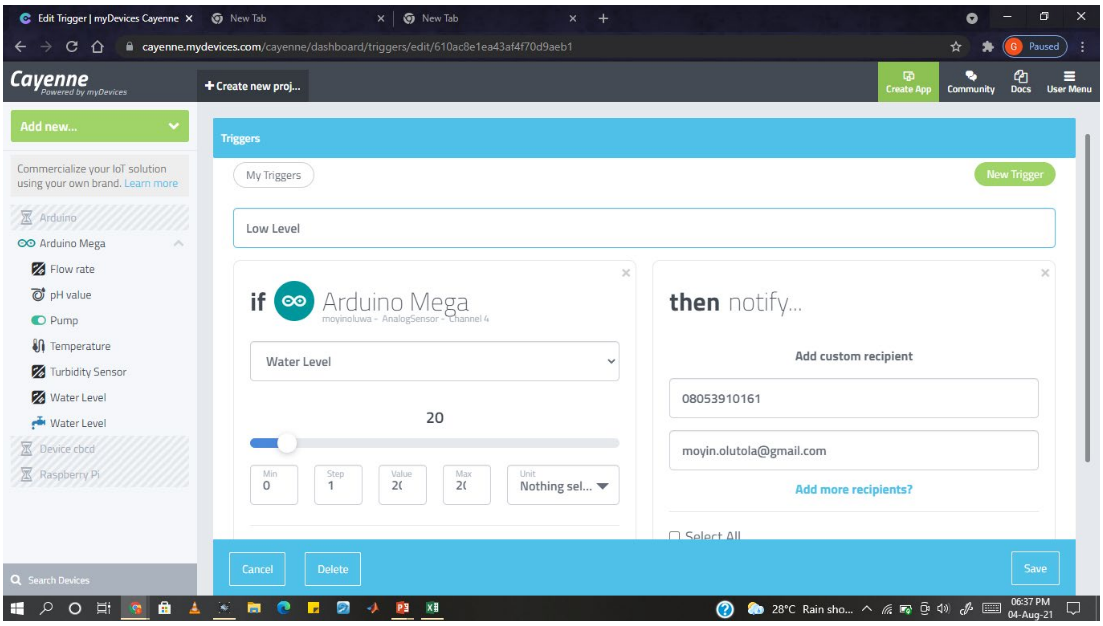

Figure 4.6 Trigger Function when water is low

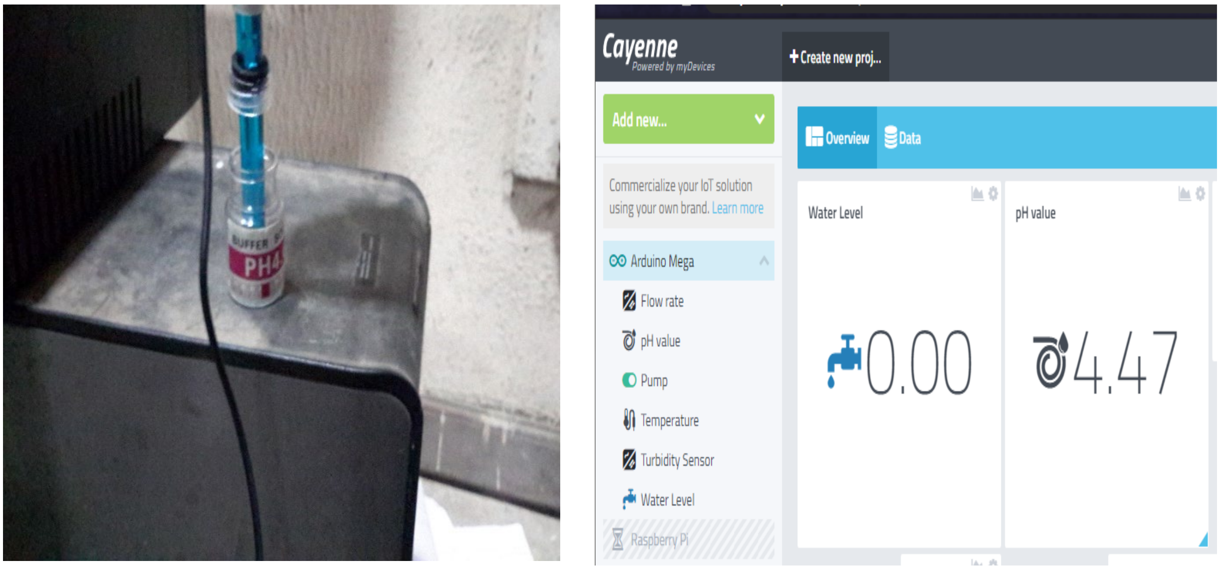

Figure 4.7 Test conducted on a buffer sample 3 of pH 4.0 and results

A test was conducted on a buffer solution with a pH value of 4.0, which is acidic on the pH scale. Figure 4.7 displays the result obtained from the Cayenne Dashboard.

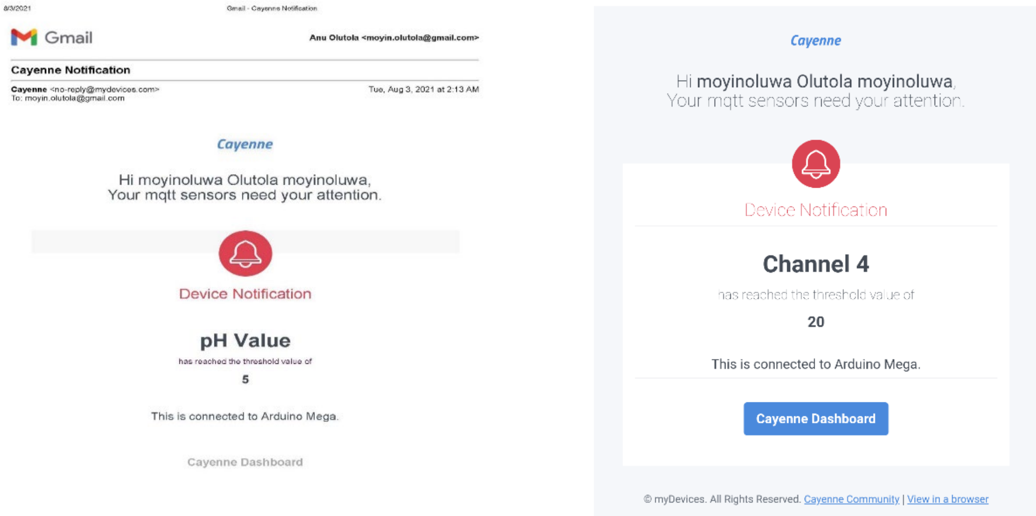

Figure 4.8 Mail alerts indicating the pH value and water channel

4.5 BILL OF ENGINEERING AND MATERIAL EVALUATION

Bill of engineering and material evaluation (BEME) indicates the list of equipment used for the project, the number of items used, and the total cost of the equipment. Table 4.1 shows the bill of engineering and material evaluation of this project

Table 4.1: Table showing the bill of engineering and material evaluation

S/N	EQUIPMENT	QUANTITY	AMOUNT (₦)
1	Containers	2	4000
2	Ultrasonic Sensor	1	2500
3	Arduino	1	10,000
4	Ph Sensor	1	15,000
5	Turbidity Sensor Module	1	8,000
6	Power Supply Module	1	6,000
7	PCB Socket Block	4	4500
8	Plastic Casing	1	1500

9	Vero Board	1	150
10	Connecting Wires	3	1500
11	Super Glue	2	100
12	5v Solid State Relay	1	1500
13	220v Ac Pump	1	7500
14	Plastic Container (Small Size)	1	700
15	Header Pin	1	300
	Total		63,250

4.6 CONCLUSION

Various tests were taken to examine the functionality and the performance of the water management system. Different samples of water were tested and the results were shown in this chapter. in completing the project, the cost of the components was also evaluated to examine the total cost of the system.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter presents various recommendations and ways to improve the system for future research, discusses about the system's achievements

5.2 SUMMARY

This paper presents an IoT-based water management system that helps to reduce and mitigate water wastage and monitor the water's overall quality, especially for drinking and domestic purposes. This will reduce the rate of water-borne diseases, especially in rural areas. The system provides the user with information and logs of the water's five parameters (pH, turbidity, temperature, water level, flow rate). The system could be applied in industries, homes, rural settings, etc.

The sensors are in the tank to measure and sense the different properties of the water and transfer them to the microprocessor, which processes and analyses the data and uploads the cloud data. A submersible pump is contained in the large tank to pump water to the monitoring tank.

5.3 RECOMMENDATIONS

For a large-scale use of this equipment or for improvements to be carried out, the following points are recommended

i. A DC source of supply can be incorporated in the design for areas with little or no electricity supply.
ii. Improved security in the software implementation to prevent intrusion.

iii. A mobile application can be designed to view and analyze the parameters of the water

iv. An automatic message or SMS that indicates the data log of the day.

5.4 ACHIEVEMENTS

The project implemented the design of a real-time monitoring system intending to monitor the level of a tank and the quality of water using various sensors to deal with the problem of water wastage, and it can help the agricultural sector to make farmers aware of the quality of water to use in their farms. The hardware system comprises a microcontroller (Arduino) and various sensors. It also consists of a submersible pump and a relay for control and protection. The water gets pumped from the reservoir to the main tank, where all the water parameters are recorded and measured by various sensors, and it sends the information to the cloud and the server. The server used is Thingspeak. It displays the information of the water graphically and records the data daily.

5.5 CONCLUSION

This research discusses the design, development of a water management system using IoT. It also presents a system that monitors water quality parameters. The proposed system consists of several quality sensors, microcontrollers, relay, flowmeter, and IoT module. These devices are cost-effective and are efficient. They can also send, view, investigate, transmit and review data via Wi-Fi to various electronic devices. This project will help to save time and resources and potentially reduce the spread of water-borne diseases and also improve the agricultural sector.

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