IoT enabled Real-Time Water Quality Monitoring System for early detection of contamination

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In the name of ALLAH, the Most Gracious, the Most Merciful

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Declaration

I hereby declare that the contents of the detailed document of **IoT enabled real-time water quality monitoring system** are project of our own research and no part has been copied from any published source (except the references). We further declare that this work has not been submitted for award of any other diploma/degree.

Muhammad Abdullah

Acknowledgement

I **Muhammad Abdullah** thank all who in one way or another contributed to the completion of this report. First, I thank to ALLAH ALMIGHTY, most magnificent and most merciful, for all his blessings. Special and heartily thanks to my supervisor **Dr**. **Muazzam Ali Khattak** who encouraged and directed me. It is with his supervision that this work came into existence. For any faults I take full responsibility. I am also deeply thankful to our informants. I want to acknowledge and appreciate their help and transparency during our research. I am also so thankful to our fellow students whose challenges and productive critics have provided new ideas to the work. Furthermore, I also thank our families who encouraged us and prayed for us throughout the time of our research. May the Almighty God richly bless all of you.

Abstract

To make sure the safe supply of drinking water to the people the quality of the water must be monitored in real time in order to achieve that IOT (Internet of Things) based real time water quality monitoring system has been developed. It has some water quality sensors which measure pH, Turbidity, Total Dissolve Solids (TDS) and Temperature of the water. The data from the sensors is sent to microcontroller like Arduino/ESP32 for processing and this processed data is transmitted to the local server or cloud for real-time data visualization on a website via Wi-Fi. In case of any deviation in water quality the officials will be notified via alert SMS or email to prevent dangerous health related problems. QR scan is also introduce for the users to get water quality status quickly. This system is be installed at computer science department of Quaid I Azam University and will further expands to other departments and it will sense any contamination in real-time and stores data in database for further processing.

Abbreviations

IoT	Internet of Things
TDS	Total Dissolved Solids
EC	Electric Conductivity
WSN	Wireless Sensor Network
TC	Test Case
SRS	Software Requirement Specification

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Chapter 1

Software Project Management Plan

1.1 Introduction

This chapter provides the description of Software Development Approach and milestones. It shows how the different goals, tasks related to software development can be arranged. It also covers which type of tools and techniques are used to develop software.

1.1.1 Project Overview

The project is an automated IoT based water quality monitoring system. In this system some water quality sensors are connected to a microcontroller and these sensors are placed in water resources. Then this data is sent to the cloud or local server from Wi-Fi enabled microcontroller. The sensors data are processed and then displayed on a website in real-time charts as well as QR scan to see real-time water quality status on mobile device .In case of severe deviation in water quality or when certain water quality parameters like Ph,Turbidity,TDS exceeds the threshold limit an alert or notifications are sent via email or SMS to related department for necessary action. This system is installed at CS department of Quaid I Azam University it senses any contamination in real time to prevent dangerous health diseases.

1.1.2 Project Deliverables

The project deliverables include:

- Project Plan.
- Software Requirement Specification (SRS).
- Activity Diagram.
- Sequence Diagram.
- Flowchart.
- Source Code.

1.2 Project Organization

Project organization consists of software process models, roles and responsibilities, Tools and Techniques.

1.2.1 Software Process Model

In this project Incremental model is used because it focuses more on testing turnover. We can add more modules/sensors according to user needs. It is also flexible.

1.2.2 Roles and Responsibilities

I am doing this project alone so overall responsibilities for the, planning, design, development, monitoring, and deployment of a project are on me.

1.2.3 Tools and Techniques

These tools are used for developing the product in each phase:

- MS word.
- Arduino IDE.
- Creatly Online UML Diagrams
- Sublime Text 3
- Local server. (xampp)
- C/C++
- Fritzing application
- Twilio SMS Service

1.2.4 Hardware Components:

The components required for the project are given below.

1. ESp32 Microcontroller
2. USB type B cable
3. Analog PH sensor + ADC board
4. Turbidity Sensor + ADC board
5. TDS (Total Dissolved Solids) Sensor
6. DS18B20 Temperature Sensor
7. Breadboard
8. 4.7k ohm resistor
9. Ph buffer solutions (4.0,6.86,10.0)
10. 5 Volt Power supply.
11. Male to female and female to female jumper wire.

1.2.4.1 Esp32 Microcontroller

The ESP32 is a Wi-Fi enabled microcontroller developed by Expressif. It is a powerful and cheap electronic device with ability to connect with multiple other devices like sensors, relays, boards. It is also equipped with Bluetooth 4.2 for serial to serial communication. Due to all these features is considered one of the best microcontroller for IoT related projects.

Figure 1 Esp32 Microcontroller

Technical specifications of the ESP32

- 32-bit LX6 microprocessor with 2 cores
- Power supply: 2.3V – 3.6V
- Current consumption: 20µA – 240mA. In Deep Sleep-Mode only 5µA
- Operating temperature range: -40°C – 125°C
- External flash memory: up to 16 MB is supported
- 36 programmable I/O pins max 20mA
- 2 analog input 0V to 1V with 12-bit resolution
- all inputs tolerate maximum 3.6V
- Wi-Fi 802.11 b/g/n 2.4 GHz with WPA/WPA2 PSK
- ipv4 and ipv6 from Arduino Core 2.5.0
- UDP and TCP with 5 simultaneous connections as maximum
- Bandwidth: 150 to 300 Kbyte/s
- Latency: < 10ms
- Bluetooth: v4.2 BR/EDR and Bluetooth Low Energy (BLE)

1.2.4.2 Analog PH sensor + ADC board

“Analog pH Sensor / Meter Kit specially designed for Arduino controllers and has convenient and practical "Gravity" connector and a bunch of features. Instant connection to your probe and your microcontroller to get pH measurements at ± 0.1pH (25 ℃). It has an LED which works as the Power Indicator, a BNC connector and PH2.0 sensor interface. To use it, just connect the pH sensor with BNC connector, and plug the PH2.0 interface into the analog input port of any Arduino controller.” (https://store.arduino.cc/usa/gravity-analog-ph-sensor, n.d.)

Figure 2 Ph sensor probe

Technical specifications of the Ph probe

- Module Power : 5.00V
- Module Size : 43 x 32mm(1.69x1.26")
- Measuring Range :0 - 14PH
- Measuring Temperature: 0 - 60 ℃
- Accuracy : ± 0.1pH (25 ℃)
- Response Time : ≤ 1min
- pH Sensor with BNC Connector
- pH2.0 Interface (3 foot patch)
- Gain Adjustment Potentiometer
- Power Indicator LED (https://store.arduino.cc/usa/gravity-analog-ph-sensor, n.d.)

1.2.4.3 Turbidity Sensor + ADC board

"The turbidity sensor detects water quality by measuring the level of turbidity. It is able to detect suspended particles in water by measuring the light transmittance and scattering rate which changes with the amount of total suspended solids (TSS) in water. As the TTS increases, the liquid turbidity level increases. This turbidity sensor has both analog and digital signal output modes. Turbidity sensors can be used in the measurement of water quality in rivers and streams, wastewater and effluent measurements, sediment transport research, and laboratory measurements." (https://wiki.dfrobot.com/Turbidity_sensor_SKU__SEN0189, n.d.)

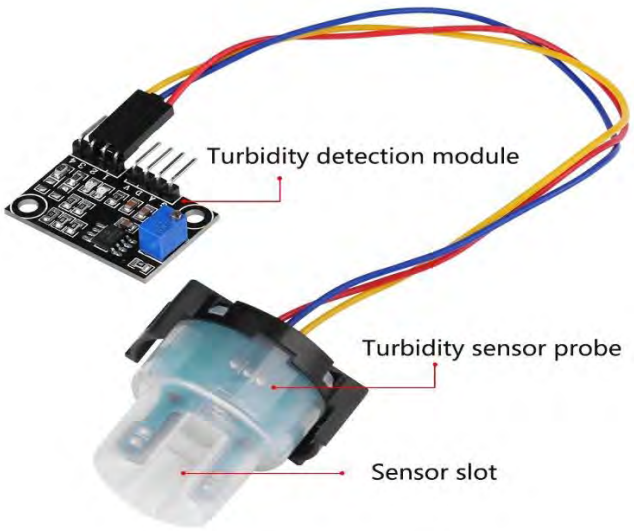

Figure 3 Turbidity Sensor

Technical specifications of the Turbidity Sensor

- Operating Voltage: 5V DC
- Operating Current: 40mA (MAX)
- Response Time: <500ms
- Insulation Resistance: 100M (Min)
- Output Method: Analog
- Analog output: 0-4.5V
- Digital Output: High/Low level signal (you can adjust the threshold value by adjusting the potentiometer)
- Operating Temperature: 5℃~90 ℃
- Storage Temperature: -10℃~90℃
- Weight: 30g
- Adapter Dimensions: 38mm*28mm*10mm/1.5inches *1.1inches*0.4inches (https://wiki.dfrobot.com/Turbidity_sensor_SKU__SEN0189, n.d.)

1.2.4.4 DS18B20 Temperature Sensor

“This is a pre-wired and waterproofed (with heat shrink) version of the DS18B20 sensor. Handy for when you need to measure something far away, or in wet conditions.. Because they are digital, you don't get any signal degradation even over long distances! These 1-wire digital temperature sensors are precise (±0.5°C over much of the range) and can give up to 12-bits of precision from the onboard digital-to-analog converter. They work great with any microcontroller.” (https://www.adafruit.com/product/381, n.d.)

Figure 4 Temperature Sensor

Technical specifications of the DS18b20 Sensor

- Usable temperature range: -55 to 125°C (-67°F to +257°F)
- 9 to 12-bit selectable resolution
- Uses 1-Wire interface- requires only one digital pin for communication
- Unique 64-bit ID burned into chip
- Multiple sensors can share one pin
- ±0.5°C Accuracy from -10°C to +85°C
- Query time is less than 750ms
- Usable with 3.0V to 5.5V power/data
- Stainless steel tube 6mm diameter by 30mm long
- Cable is 36" long / 91cm, 4mm diameter

  (https://www.adafruit.com/product/381, n.d.)

1.2.4.5 Analog TDS Sensor

“This is an Arduino-compatible TDS sensor/Meter Kit for measuring TDS value of the water, to reflect the cleanliness of the water. It can be applied to domestic water, hydroponic and

other fields of water quality testing. TDS (Total Dissolved Solids) indicates that how many milligrams of soluble solids dissolved in one liter of water. In general, the higher the TDS value, the more soluble solids dissolved in water, and the less clean the water is. Therefore, the TDS value can be used as one of the references for reflecting the cleanliness of water."

(https://www.instock.pk/dfrobot-analog-tds-sensor-meter-for-arduino.html, n.d.)

Figure 5 TDS Sensor

Technical specifications of the TDS Sensor

- Input Voltage: 3.3 ~ 5.5V
- Output Voltage: 0 ~ 2.3V
- Working Current: 3 ~ 6mA
- TDS Measurement Range: 0 ~ 1000ppm
- TDS Measurement Accuracy: ± 10% F.S. (25 ℃)
- Module Size: 42 * 32mm
- Module Interface: PH2.0-3P
- Electrode Interface: XH2.54-2P
- Number of Needle: 2
- Total Length: 83cm
- Color: Black
- Other: Waterproof Probe
  (https://www.instock.pk/dfrobot-analog-tds-sensor-meter-for-arduino.html, n.d.)

1.2.4.6 Breadboard

A breadboard is a solderless device that is used for electronics and test circuit designs. The top and bottom rows of holes are connected horizontally and the middle rows on this board are connected vertically. The breadboard has strips of metal underneath the board and connect the holes on the top of the board.

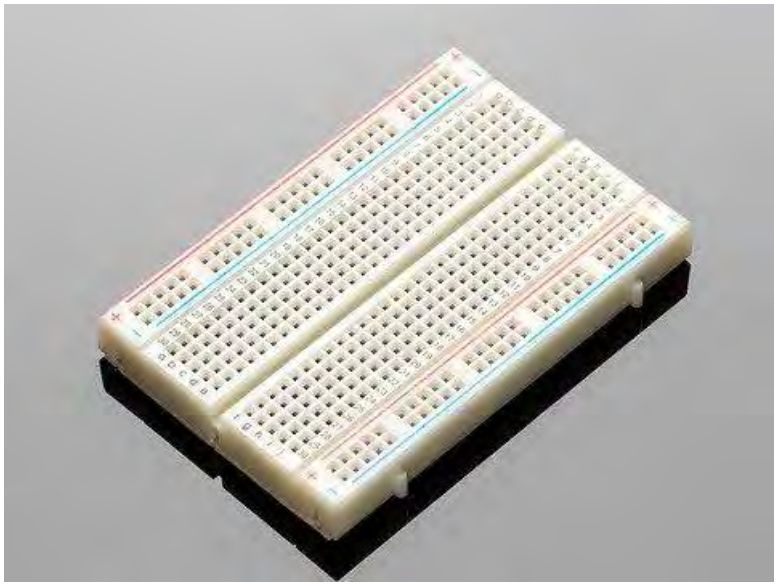

Figure 6 Breadboard

1.2.4.7 Jumper Wires

Jumper wires are wires that have connector pins at each end. Jumper wires are used with breadboards sensors and other electric modules in order to make circuits easily without any soldering and these wires can be changed easily.

Figure 7 jumper wires

1.3 Project Management Plan

This section describes the project tasks, milestones, and deliverables of this project.

1.3.1 Tasks

The project has the following tasks.

1.3.1.1 Problem Understanding

- **Description**
  In this task project deliverables, milestones and resources needed will be described.

- **Dependencies and Constraints**
  None

- **Risks and Contingencies**
  None

1.3.1.2 Software Project Management Plan

- **Description**
  In this task the software approach and associated milestones will be included. It describes functional and non-functional requirements of the proposed system. It also includes a set of use cases that describe user interaction.

- **Deliverables**
  SPMP

- **Resources Needed**
  Lucidchart, Ms word

- **Dependencies and Constraints**
  Problem Understanding

- **Risks and Contingencies**
  None

1.3.1.3 Analysis and Requirement

- **Description**

In order to understand customer requirements and satisfy customers with actual product, analysis of requirement is necessary. It will reduce the cost and time.

- **Deliverables**

SRS

- **Dependencies and Constraints**

Software Project Management Plan

- **Risks and Contingencies**

None

1.3.1.4 Develop System Design

- **Description**

To minimize the complexity of implementation, it is necessary to design a working flow of software so that all scenarios can be clarified.

- **Deliverable**

Software Design Description

- **Dependencies and Constraints**

Requirements analysis

- **Risks and Contingencies**

None

1.3.1.5 Software Implementation

- **Description**

To write error free code, software test documentation is an essential task in software development process. It reduces time and effort.

- **Resources Needed**

Laptop, Arduino IDE

- **Dependencies and Constraints**

Software design description

- **Risks and Contingencies**

None

1.3.1.6 Software Test Documentation

- **Description**

In this task, we develop a plan for the implementation of the project.

- **Deliverables**

Software Implementation Document (SID)

- **Dependencies and Constraints**

Software design description

- **Risks and Contingencies**

None.

1.3.2 Project Cost

S. No	Items	Amount (Rs.)
i)	*ESP32 Microcontroller*	950
ii)	*Analog Turbidity Sensor*	2,250
iii)	*Ph Sensor*	6,200
iv)	*Waterproof Temperature Sensor*	220
v)	*Breadboard*	130
vi)	*Jumper wires*	350
vii)	*Ph buffer Solutions*	600
viii)	*Shipping Charges*	350
ix)	**Total Cost**	**11,050**

Table 1 Project cost

Chapter Summary

Following is the brief overview about the remaining chapters of the documentation, this chapter describes the objective and scope of the proposed system. It also describes problem definition and proposed solution of the system with different perspectives. The next chapter describes the requirements analysis of the system, in which functional and non-functional requirements and use cases are specified. Use case description describes that how the user can use this application. Third chapter describes the design of the system. This chapter includes the detailed architecture of the system. The chapter also discusses functional design and interface design of the system. Fourth chapter is related to system implementation. It describes the tools used in development of the application. Fifth chapter is all about testing the test case are created against the use cases as described in requirement analysis phase. Sixth chapter contains the conclusion of project and future enhancements.

Chapter 2

Software Requirements Specification

2.1 Introduction

A software requirement Specification is a document that provides an overview for the IoT based water quality monitoring system. Its main aim is to provide a clear and descriptive statement of user requirement for further development of the software. Software requirement specification contains problem statement, related work, project overview, project scope, project objective, functional and non-functional requirements, Use cases and their detailed descriptions, interaction between user and system. This chapter also defines user characteristics and operating environments. The software requirements specification describes the details, that how the system is expected to perform in different scenarios.

2.1.1 Problem statement

Making sure that the quality of water is at a standard is a difficult task because there are so many sources of pollutants which affect the quality of water. The main reason is the pace in the industrial development. Natural resources are being used unfairly. The agricultural growth is made dependent on the use of chemical fertilizers so heavy rainfall washed them into streams and lakes causing hypertrophication this leads to the excessive growth of algae which pollute the water. There are no laws to control that. All these issues make up to increase the water pollution. In traditional water quality monitoring the water samples are collected from different locations of water resources. These water samples then diagnosed in the laboratory and tested with different analytical approaches. These techniques consume a lot of time to produce results and are not considered efficient thus giving rise to the need of development of a better, less time-consuming technique to observe the quality of the water in real time.

2.1.2 Motivation

Water is a key element to life it covers all the aspect of our lives from public health to safety to the foundation of our economy, we use water in a million different ways. Water serves several essential functions and is a primary component of every cell in the human body. In July 2017 thousands of fishes found dead in Rawal Lake Islamabad due to contamination of water. Officials said that public at large is now at risk due to apprehensions of deaths of fish and serious dangers to health. What if contamination of water detected at early stage and notified to official about poisonous water in lake? we could really overcome this disaster. We are in fourth industrial revolution(4IR) and the heart of 4IR is **Internet of things**. It is playing a significant role in automation and various fields for monitoring, collecting, and analysis of data from remote locations over the internet. Everything is becoming smart we

have smart homes, smart wearables, smart cities, smart traffic, smart cars, smart hospitals, and smart agriculture. IoT can also be implemented in the field of water quality monitoring and the whole water supply can be automated. Using IoT we can make a water quality monitoring and controlling system for homes ,agriculture ,water reservoirs with a network of sensors ,microcontrollers connected to generate data related to water quality .Authorities can be alerted instantly in case of severe deviation in water quality parameters or system can also stop the supply of water to prevent dangerous health related problem caused by contaminated water .

2.1.3 Proposed Solution

We are also using IoT technology for the real-time water quality monitoring where different sensors, devices deployed at various locations of water resources to gather data, which is used for decision making, prevention and diagnosis of water diseases. We present a model where water quality sensors are submerged in water and are connected to microcontroller. The sensor's data is sent to microcontroller where it is processed, and then sent to the cloud or local server. Additionally, web-based application is developed which is connected with IoT devices and the data obtained from the sensors are be displayed on it in real-time charts, tables and maps. In case of severe deviation in water quality or when certain water quality parameters like Ph, Turbidity, TDS etc. exceeds the threshold limit alert or notification is sent to Smartphone via SMS to officials for necessary precaution.

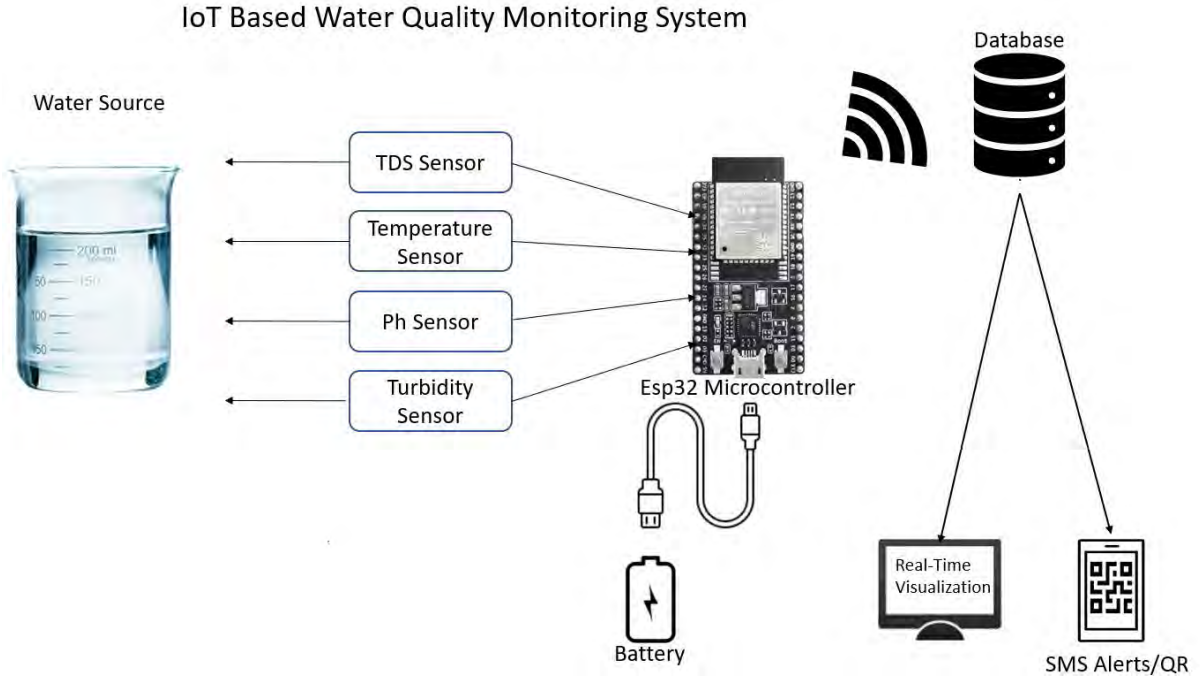

Figure 8 System Block Diagram

2.2 Project Scope

The scope of this project is:

- User can scan QR code to see real-time water quality.
- For QR Scan user do not need login.
- User and microcontroller must connect with same Wi-Fi connection to see water quality status using scan QR
- Admin can create new login for users to access website.
- Admin can download sensor data.
- Admin can download charts.
- Admin has to login to create new user, download sensor data or charts.
- TDS Sensor operates between -10 °C ~ 55 °C.
- Temperature sensor operates between -55~125°C.
- Turbidity sensor operates between 5℃~90 ℃
- Ph sensor needs water temperature to correctly detect PH of the water.

2.3 Project Objective

The primary goal of this project is to make sure the safe supply of drinking water to the people. To achieve this, we provide facility to user so they can scan QR code to see water quality status quickly.

2.4 Product Perspective

There are many types of interfaces supported by the system namely, User Interface, Software Interface, Hardware Interface, and External interface. Details of requirements are given below:

2.4.1 Hardware Interfaces

Keyboard, mouse, laptop and mobile phone is used to scan Qr code and to display output.

2.4.2 Software Interface

Operating system: Windows

Database: MySQL

2.5 Related Work

Following are the related work regarding this project.

2.5.1 Smart and Low-Cost Real-Time Water Quality Monitoring System Using IoT

This project proposes a Sensor-Based Water Quality Monitoring System which is used for measuring physical and chemical parameters of the water. The parameters such as Temperature, pH, TDS and water level of the water can be measured, and the system provides a visual image of interior part of water container using raspberry pi camera. The measured values from the sensors can be processed by the core controller. The Raspberry Pi model can be used as a core controller. Finally, the sensor data can be viewed on internet using cloud storage (Thingspeak). The system also provides an alert to a remote user, when there is a deviation of water quality parameters from the predefined set of standard values. [1]

2.5.2 A system for monitoring water quality in a large aquatic area using wireless sensor network technology

It is a low cost, real-time water quality monitoring system which can be applied in remote rivers, lakes, coastal areas and other water bodies is presented. The main hardware of the system consists of off-the-shelf electrochemical sensors, a microcontroller, a wireless communication system and the customized buoy. It detects water temperature, dissolved oxygen and pH in a pre-programmed time interval. The developed prototype disseminates the gathered information in graphical and tabular formats through a customized web-based portal and preregistered mobile phones to better serve relevant end-users. To check the system effectivity, the buoy's stability in harsh environmental conditions, system energy consumption, data transmission efficiency and web-based display of information were carefully evaluated. [2]

2.5.3 Smart Water Management using IOT

Design a system to limit the usage of water. They set up this system in residential societies and continuously monitor the level of water tank. Homeowner will install an android application in his smart phone for getting regular information of water level. The data will be stored on the cloud and if he or she is connected to Wi-Fi then he or she will have access to data. There will be a motor submerge into the tank and according to the level of water and requirement it can be switched on or off. [3]

2.6 Stakeholders

This system is for all Quaid I Azam university students, faculty members and staff. Other people can also use only QR scan feature.

2.7 Functional Requirements

The major functional requirements of the application are as following:

- Only admin is able to create new login for website access.
- System must be connected to internet for data storage and retrieval.
- User must have WIFI connection to use QR.

- PH sensor should get correct PH between 0 and 15.
- Temperature sensor should get correct temperature between -55 to 125
- Turbidity sensor should get correct NTU between 0 and 5.
- The website should allow the admin to download sensor data in csv format.
- The website must allow admin to download charts.
- The web application must send SMS to user if he/she forgets password/username.
- System must send SMS notifications to admin in case of water contamination.

2.8 Non - Functional Requirements

The major functional requirements of the application are as following:

- The webserver should not take more than 10 seconds to update data.
- The web application should update charts every hour.
- It should support large number of clients.
- If any error occurs or hardware fails it can be easily maintained by the system administrator after the deployment
- Performing any operation and understanding the functioning of website should be easy.

2.9 Software System Attributes

Following are the software system attributes:

2.9.1 Reliability

- The probability of failure is zero.
- The system shall never crash, other than as the result of an operating system error.
- If an error occurs, then it will display an appropriate message.
- Reliability of system is approximately more than 90-95%.

2.9.2 Availability

For availability, it requires the following conditions:

- Internet Connection

- Database Connectivity
- Sensors
- Microcontroller

2.9.3 Maintainability

If there is any fault detected in the future, then it will be easy to correct and modify the existing code. The application can also be upgraded for new features.

2.9.4 Performance

- The web application should not take more than 5 seconds to load.
- User Interfaces should be opened in maximum 5 seconds.
- The response time of the application should not be more than 5 seconds.

2.10 Actors

The use case documents the interactions between the system and the actors to achieve the goals

- Admin
- User
- System Administrator

2.11 List of Use Cases

Use cases are the list of steps or events performed by user to achieve a goal. List of use cases are as following:

- Login
- Scan QR Code
- View Charts
- Download charts
- Download sensor data
- Send email
- Create new user login

- Logout
- Reconfigure sensors and microcontroller

2.12 Use Case Diagram

Use case diagram is a graphical representation of a user's interaction with the system. A use case diagram shows the actors, use cases and the relationship among them.

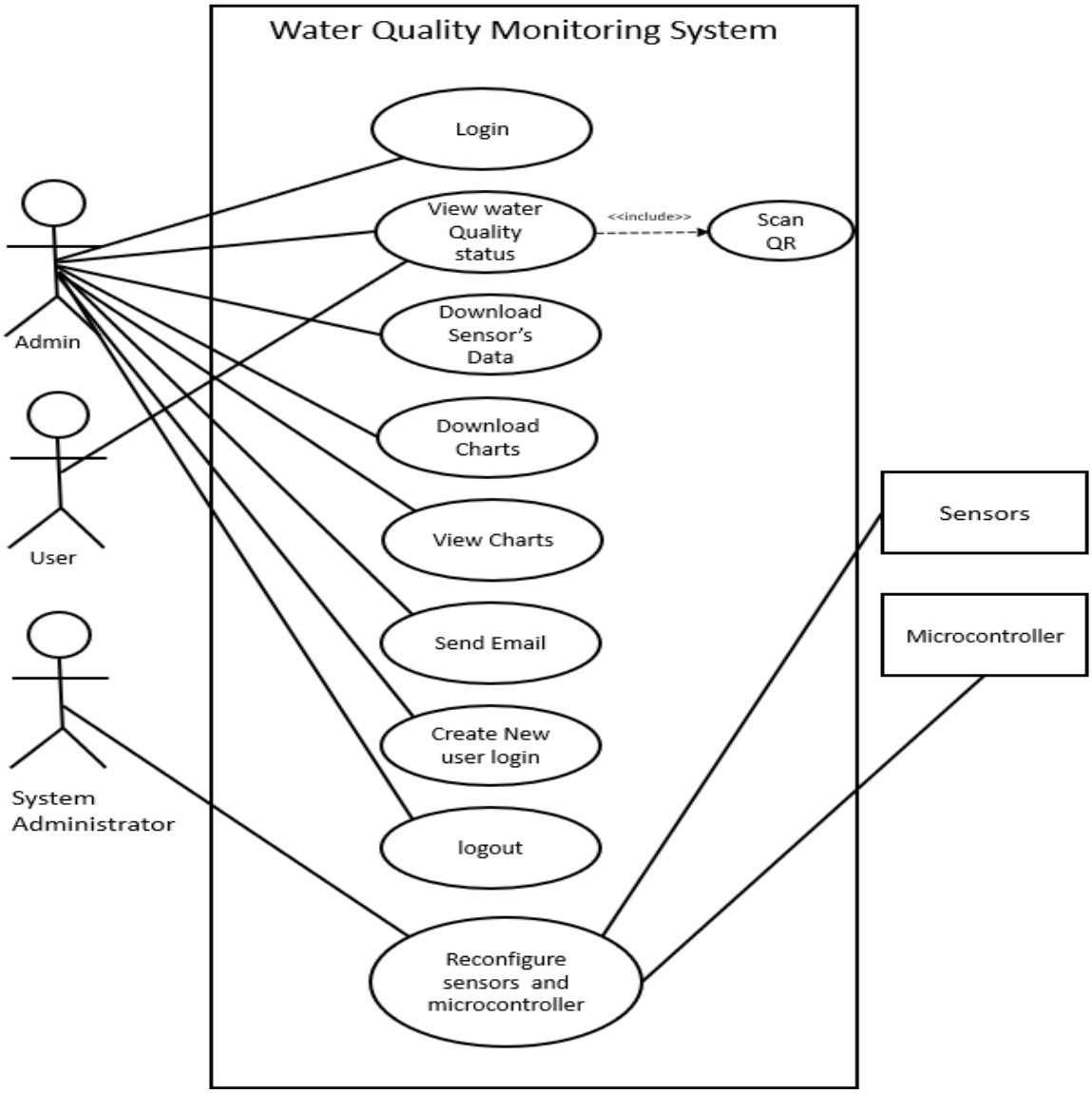

Figure 9 Use Case Diagram

2.13 Use Case Description

A use case description is a step-by-step interaction between the actor and the system. It describes the outcomes of an action taken to accomplish a specific goal. It also details different paths that can be followed by defining primary, alternate, and exception flows.

Use case #1: Login

Primary Actor	Admin
Pre-Conditions	Admin must have an account.
Post Conditions	Admin successfully signed in into system.
Main Success Scenario	1). Open login page of website 2). Admin enters username and password. 3)And clicks the login button.
Extensions	1. Username and Password entered are incorrect. 1a) System prompts message that the data is incorrect.
Technology/Tools	• Pc or Laptop • Internet connection
Frequency	Several times a day

Table 1 Login

Use case #2: View water quality status

Primary Actor	Admin, User
Pre-Conditions	Must have Wi-Fi connection. QR Scanner must be installed on phone. System must connect with Wi-Fi.
Post Conditions	Water quality status displayed.
Main Success Scenario	1. Connect to Wi-Fi connection. 2. Open QR scanner application.

	3. Scan QR Code.
Extensions	1. Internet connection fail. 1a) Refresh internet:
Technology	• Android/iPhone mobile. • Internet connection.
Frequency	Several times a day.

Table 2 View water Quality Status

Use case #3: Download Chart

Primary Actor	Admin
Pre-Conditions	Database must have data. Internet connection is enabled.
Post Conditions	Chart downloaded
Main Success Scenario	1. Open login page 2. Enter username and password 3. Click log In 4. Click top-right icon on chart. 5. Select desired download format. 6. Click download chart
Extensions	1. Internet connection fail. 1a) Refresh internet 1b) Reload webpage 2.User Authentication fail. 2a) Enter Correct username & password. 2b) Click login in.

Tools/Technology	• Laptop or PC • Internet connection.
Frequency	2-3 times a day

Table 3 Download chart

Use case #4: View Charts

Primary Actor	Admin
Pre-Conditions	Internet connection is enabled. Database must have data.
Post Conditions	Charts displayed.
Main Success Scenario	1. Open website login page 2. Enter username and password. 3. Click log in
Extensions	1. Internet connection fail. 1a) Refresh internet. 1b) Reload webpage. 2.User Authentication fail. 2a) Enter Correct username & password. 2b) click login
Tools/Technology	• Laptop or PC • Internet connection.
Frequency	Several times a day

Table 4 View Charts

Use case #5: Download Sensor Data

Primary Actor	Admin
Pre-Conditions	Database must have data.

	Internet connection is enabled.
Post Conditions	Sensor data download successfully
Main Success Scenario	1. Open login page 2. Enter username and password 3. Click log In 4. Click top-right icon on chart. 5. Click download CSV/XLS.
Extensions	1. Internet connection fail. 1a) Refresh internet. 1b) Reload webpage. 2.User Authentication fail. 2a) Enter Correct username & password. 2b) click login
Tools/Technology	• Android cell phone. • Internet connection
Frequency	Several times a month

Table 5 Download Sensor Data

Use case #6: send email

Primary Actor	Admin
Pre-Conditions	User must be logged in.
Post Conditions	User sent email successfully.
Main Success Scenario	1. Click on contact us button 2. Enter First and last name 3. Enter Email 4. Enter Mobile number 5. Enter Subject

	6. Enter message 7. Click on Submit Message
Extensions	1. Internet connection fail. 1a) Refresh internet. 1b) Reload webpage.
Tools/Technology	• PC or Laptop • Internet
Frequency	Several times a month

Table 6 Send email

Use case #7: Logout

Primary Actor	Admin
Pre-Conditions	Admin must be logged in.
Post Conditions	Admin Logged out.
Main Success Scenario	1. Click on the log out button.
Extensions	None
Tools/Technology	• Pc or Laptop. • Internet connection
Frequency	Several times a day

Table 7 Logout

Use case #7: Reconfigure sensors and microcontroller

Primary Actor	System Administrator
Pre-Conditions	No precondition
Post Conditions	Sensors and microcontroller configured
Main Success Scenario	1. Open arduino ide on laptop. 2. Connect microcontroller to laptop using USB cable.

	3. Write code in arduino ide for configuring microcontroller 4. Upload code in microcontroller. 5. Verify new configuration using arduino serial monitor
Extensions	None
Tools and technology	• Laptop. • USB type B cable • Microcontroller • Arduino IDE • Internet connection
Frequency	Once in a month

Table 8 Reconfigure sensors and microcontroller

2.14 Flow Chart

A flowchart is a graphical representation of how the system operates. Flowcharts play an important role in displaying information and assisting reasoning. It us visualize complex processes or make explicit the structure of problems and tasks. A flowchart can also be used to define a process or project to be implemented.

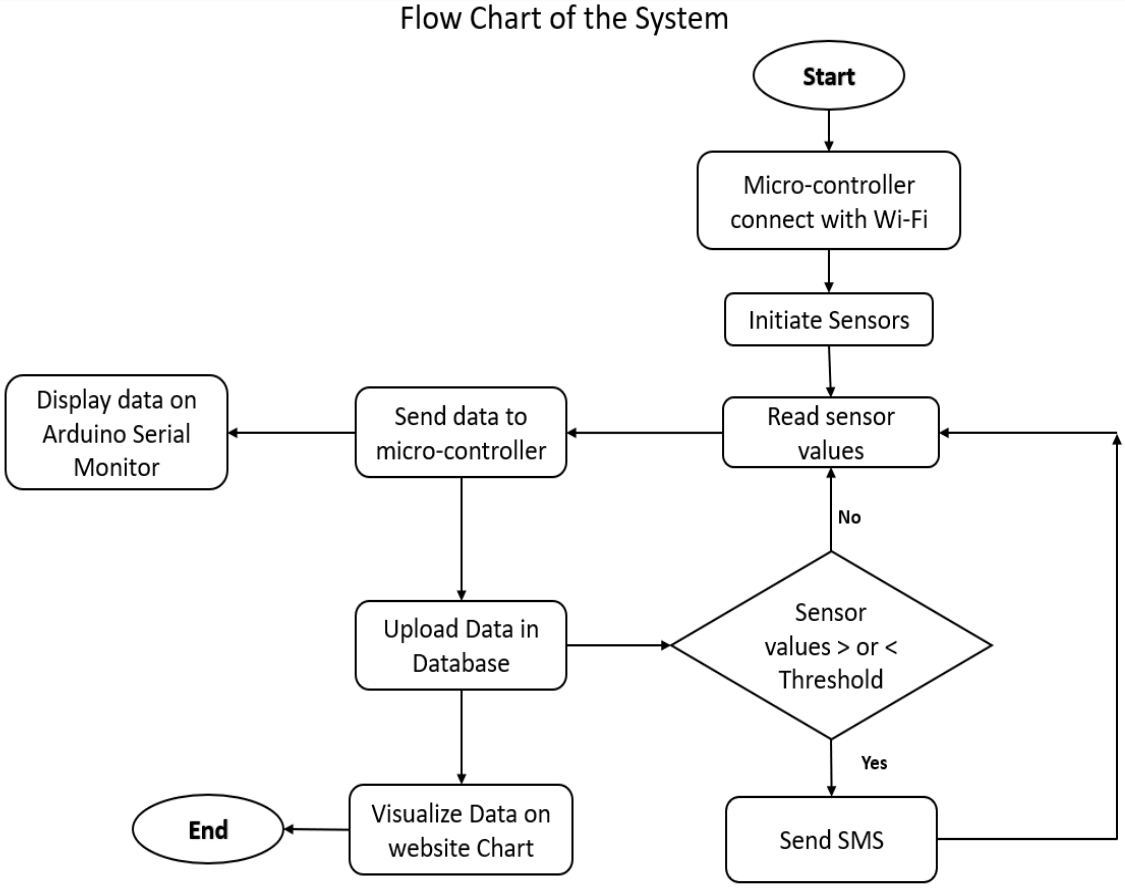

Figure 10 Flow chart

2.15 Sequence Diagram

Sequence Diagrams are interaction diagrams that detail how operations are carried out. They capture the interaction between objects in the context of a collaboration. Sequence Diagrams are time focus and they show the order of the interaction visually by using the vertical axis of the diagram to represent time what messages are sent and when.

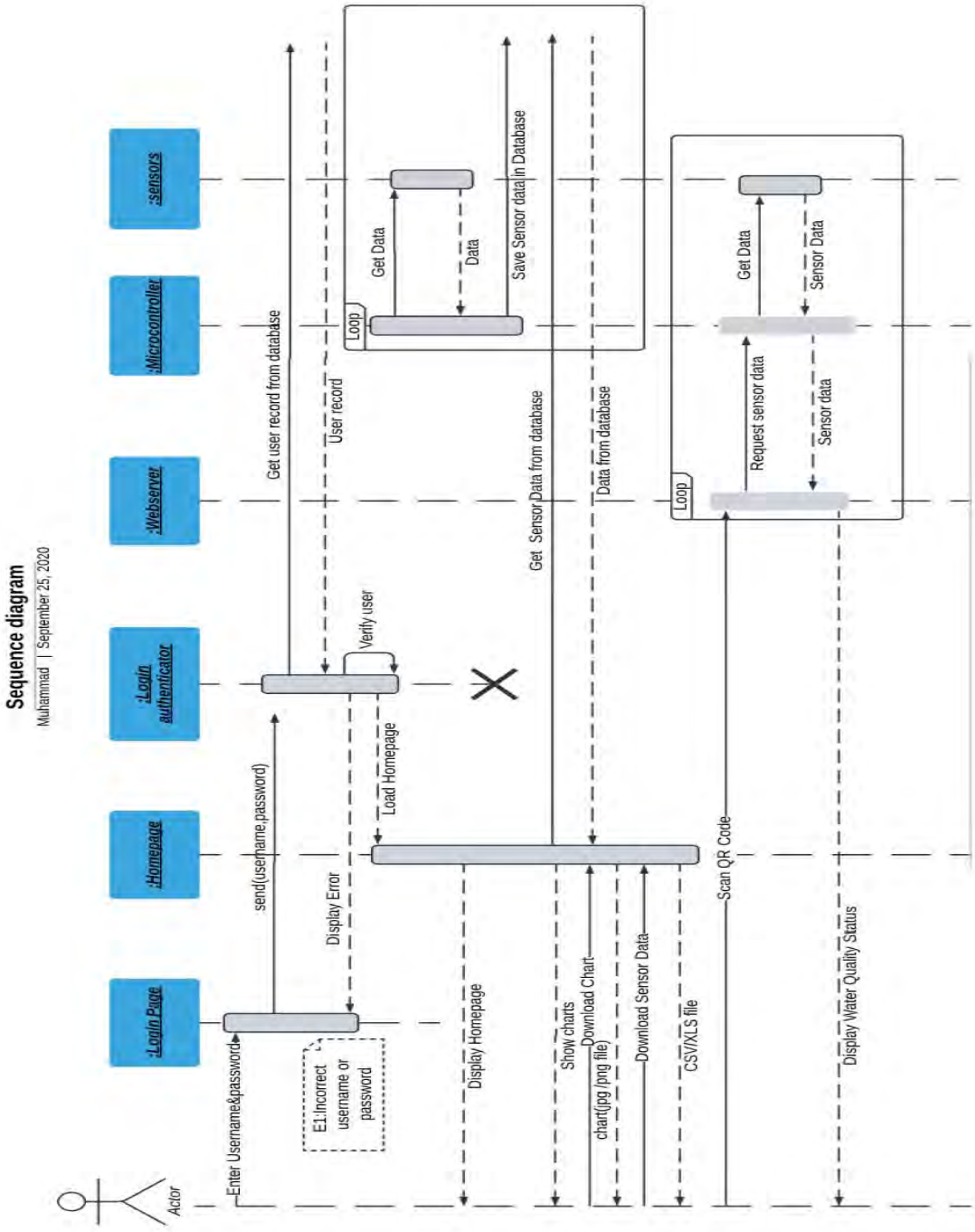

Figure 11 Sequence Diagram

2.16 Activity Diagram

A sequence diagram shows the time relevant objects interaction. It shows how objects collaborate and in what order. It is used to illustrate messaging between software objects. They are used primarily to show the interactions between objects in the sequential order and sequence or time ordering of messages.

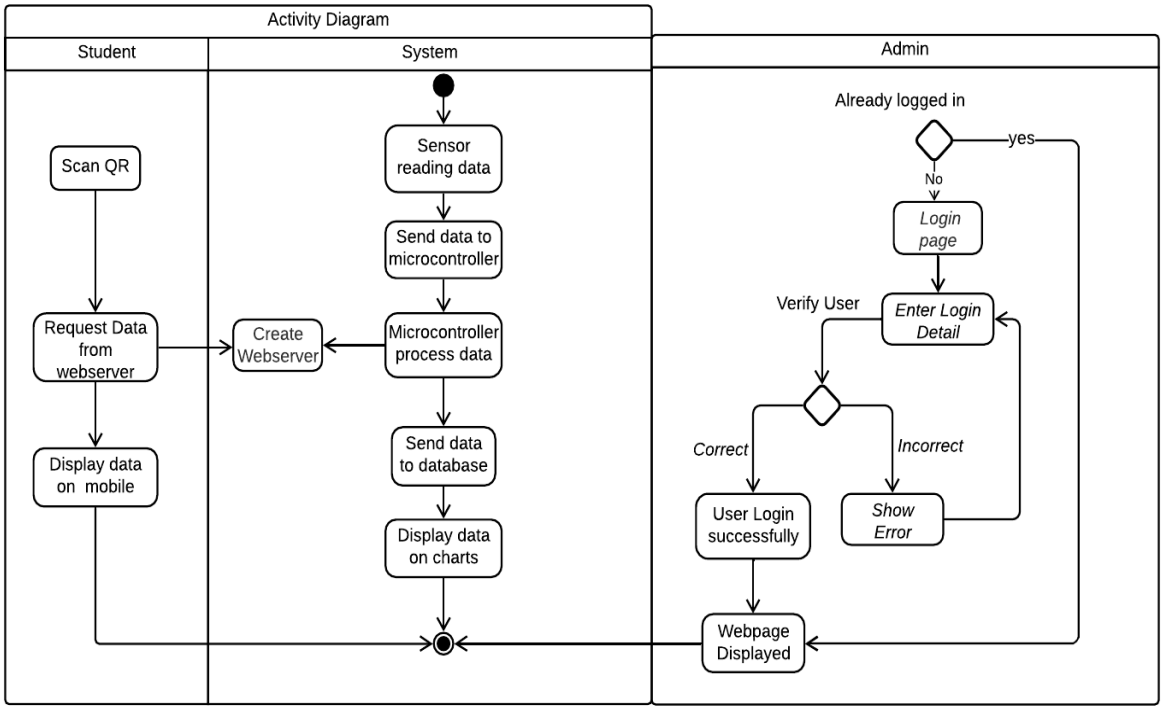

Figure 12 Activity Diagram

2.17 Database Requirements

MySQL database will be used for this application to store all sensor's data and user credentials. MySQL is a database used on the web and runs on the server it is fast, reliable, and easy to use. The data in a MySQL database are stored in tables. A table is a collection of related data, and it consists of columns and rows. The database will serve as the backbone of Web application. It will allow the user information, sensor data to be captured, stored, and then display in various forms to each user.

Chapter Summary

The chapter specifies all the requirements of the application. As it defines stakeholders, functional and non-functional requirements. Also, the use cases are identified to obtain a detailed look of all the functionalities which the application should provide. Different diagrams are provided to help in better understanding. After clarification of the requirements the next chapter is related to design of the application.

Chapter 3

System Design specification

3.1 Introduction

This chapter describes the system design of the proposed system. System design defines the architecture, components, modules, and data for a system to satisfy specified requirements. This chapter also contains design of user interfaces. The system design visually describes the system requirements, operating environment, system and subsystem architecture, files and database design, input formats, output layouts, human-machine interfaces, detailed design, processing logic, and external interfaces.

3.2 System Architecture

System architecture is the conceptual model that describes the high-level structure and behavior of a system. It is used to represent the components of the system and interaction between them. The application is based on "Three Tier Architecture". Three-tier architecture permits any one of the three tiers to be redesigned or changed independently without affecting the outer two layers, this is the most important reason to use this architecture design.

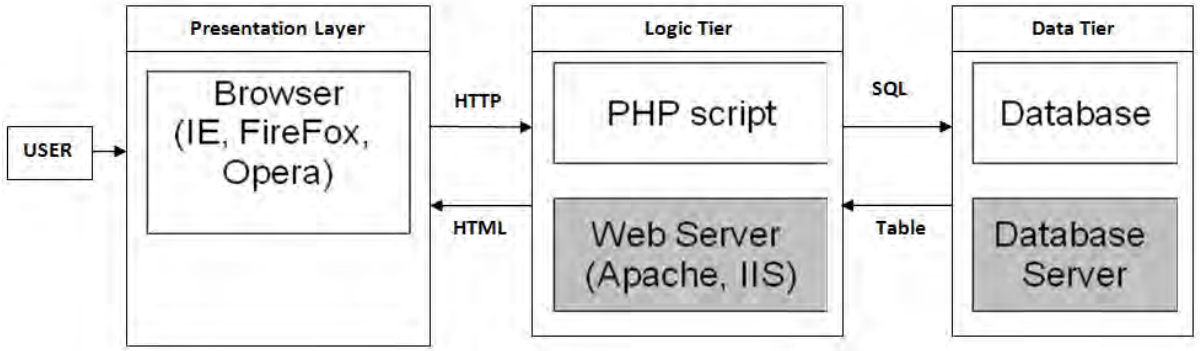

Figure 13 Architecture design

3.2.1 User Interface

This layer is also known as "Presentation Tier". It contains the user interface with which user interacts and this tier communicates with another tier to fulfill the user request. Different user interfaces require data related to user requirement so that all set users can use it easily. These interfaces will communicate with application tier as all business logic related to insertion is part of the application tier.

3.2.2 Business Logic

This layer is also known as “Application Tier”. The functionality will be handled through this layer such as insertion and updating. Presentation tier will interact with this tier for insertion and retrieval of data. Application tier further interacts with data tier to store the data after processing on it.

3.2.3 Database

This layer is also known as “Data Tier”. After all processing performed in application tier, all data stored in data tier can be used when required. Presentation tier interacts with this tier only for retrieval of data. The tiers are explained with the help of the given architecture diagram.

Chapter Summary

The chapter illustrates the architecture diagram, class diagram and sequence diagrams of developing application. After the completion of the system design it can be implemented. Next chapter will describe details about the implementation of the application and the interfaces will be implemented according to the layout of user interface.

Chapter 04

System Implementation Document

4.1 Introduction

After the completion of detailed design phase, the next phase is implementation phase. This chapter describes the selection of functional design, design artifacts, tools, framework, languages, software, libraries, and technologies which are used in the implementation of Water Quality monitoring System. The main purpose of the implementation phase is to convert the selected design into an executable form of code.

4.2 Programming Language Selection

The first step in implementation is to decide the suitable language that must be flexible enough to support design. C++ is used for coding of Esp32 microcontroller and HTML, CSS, PHP, JAVASCRIPT, AJAX, JQEURY is used for web application development.

4.3 Platform Selection

As there are multiple platforms available for the development but in this project, Arduino IDE has been selected as platform for coding of Esp32 Microcontroller. Microsoft Word 2016 has been selected as platform for documentation. A tool lucid chart and MS PowerPoint has been selected as design diagrams. Sublime Text 3 tool is used for the coding of website for data visualization.

4.3.1 Arduino IDE

The Arduino (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards. Every Arduino Sketch has two function setup() and loop().

Setup ()

This function defines the initial state of the Arduino upon boot and runs only once.

1. Initial state of pins
2. Initialize classes
3. Initialize variables
4. Code logic

Loop ()

The loop function is also a must for every Arduino sketch and executes once setup () is complete. It is the main function and as its name hints, it runs in a loop repeatedly. The loop describes the main logic of your circuit.

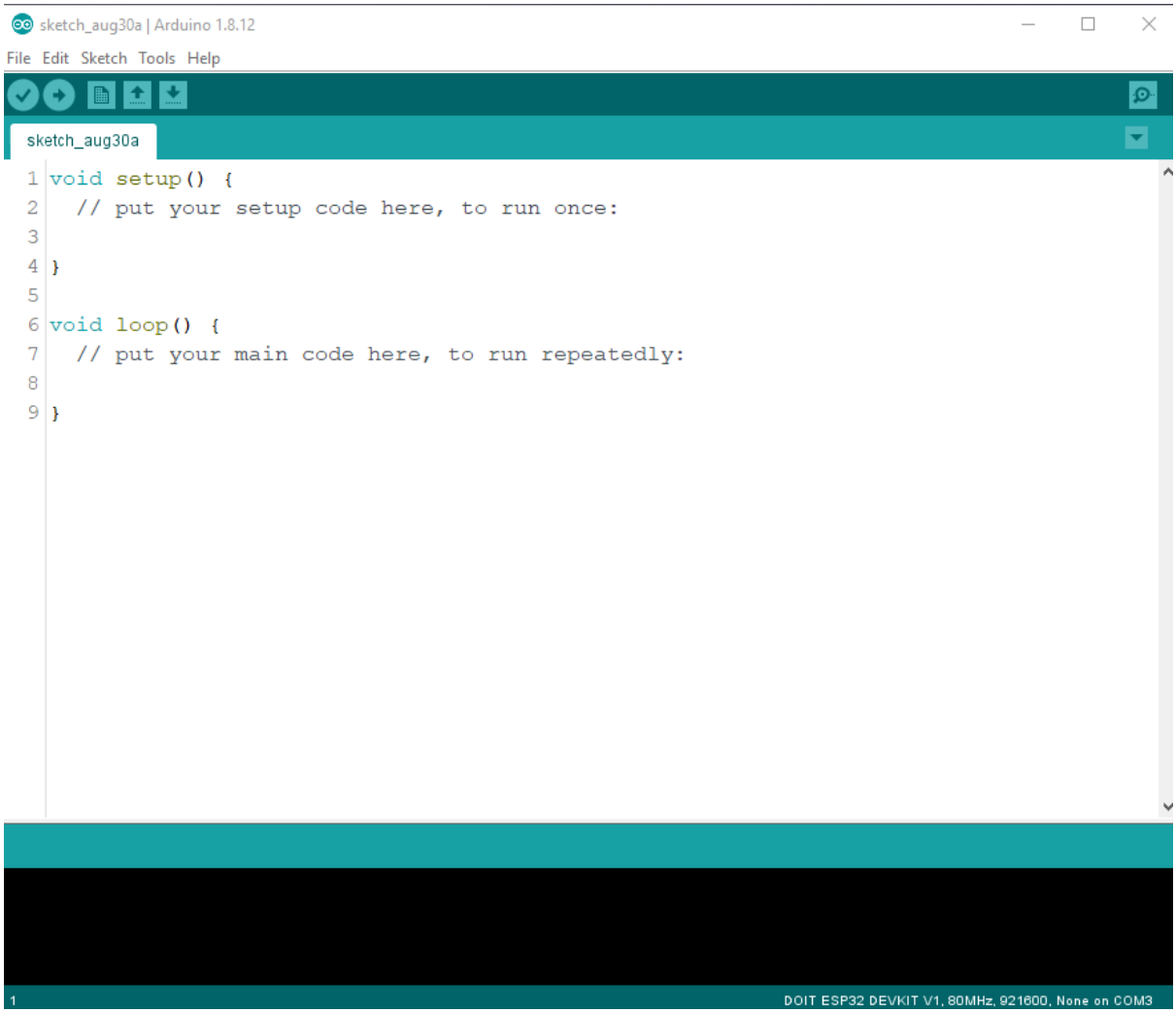

Figure 14 Arduino IDE

4.3.2 Sublime Text 3

Sublime Text 3 is a text editor used for coding and to design web based application it allows you to be able to write code efficiently.

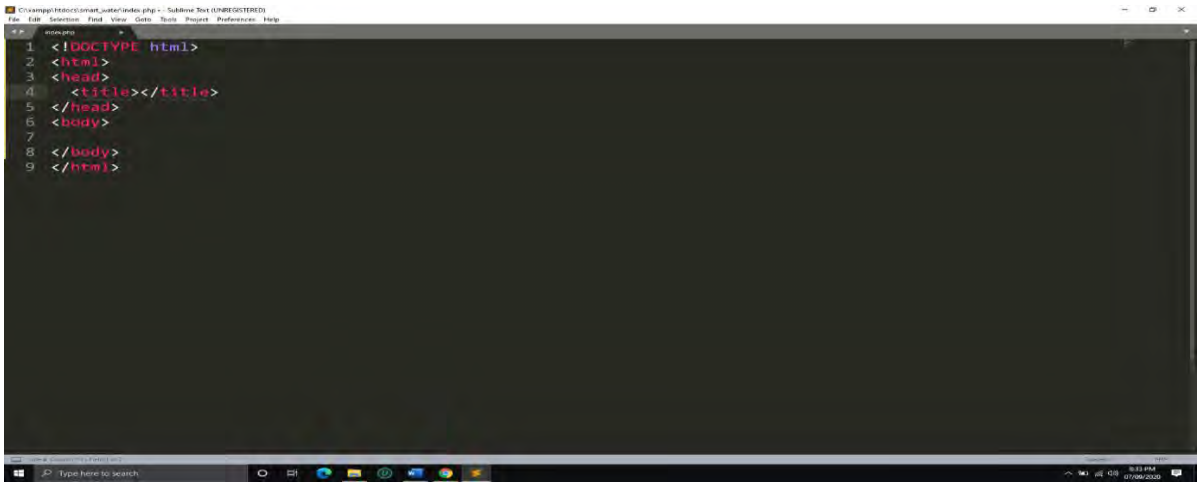

Figure 15 Sublime Text 3

4.4 User Interfaces

4.4.1 Admin Login Activity

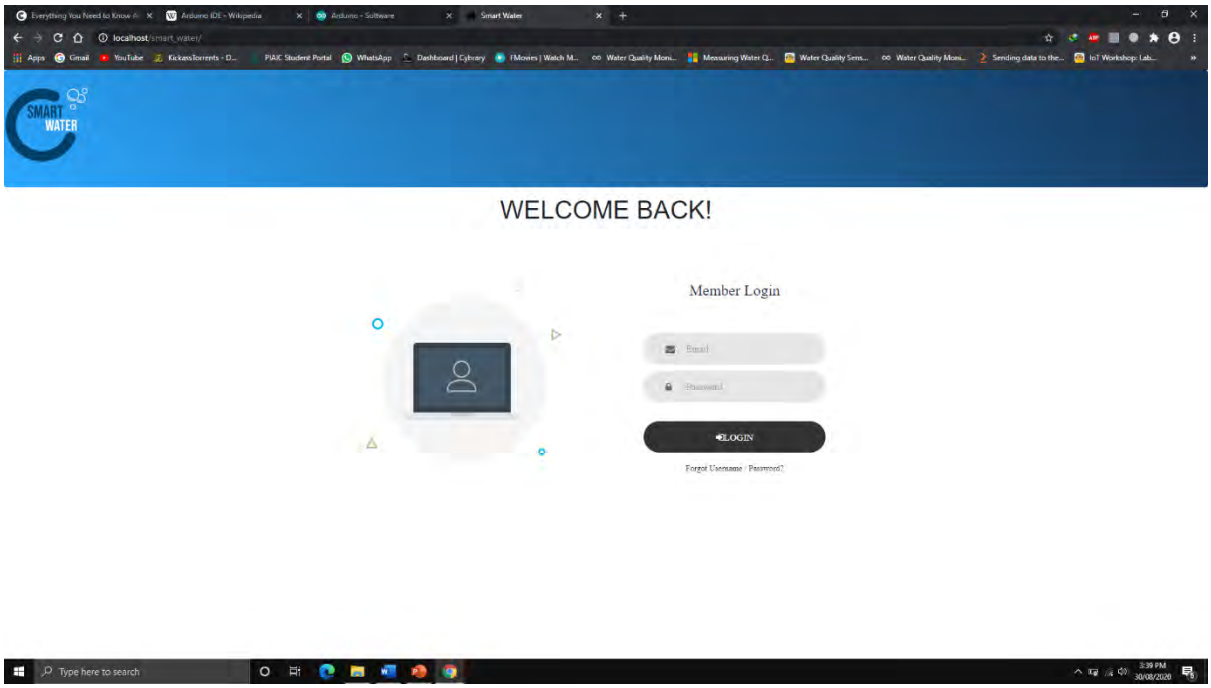

Figure 16 Admin login Activity

4.4.2 Main Dashboard

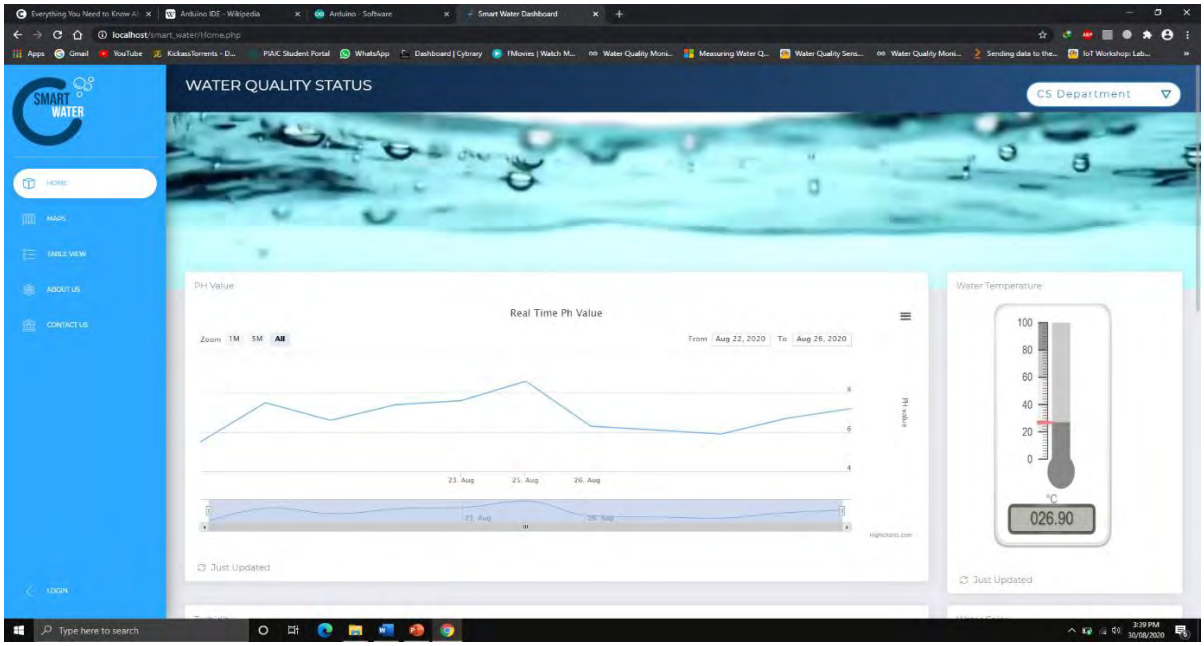

Figure 17 Main Dashboard 1

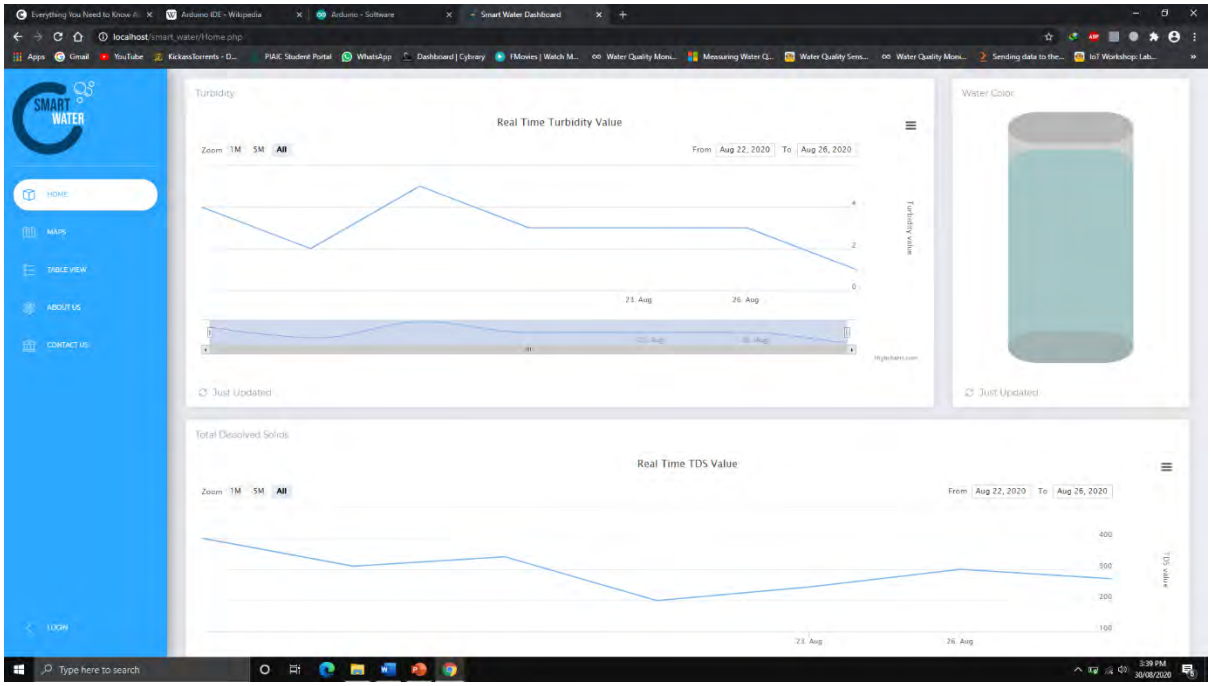

Figure 18 Main Dashboard 2

4.4.3 Map View

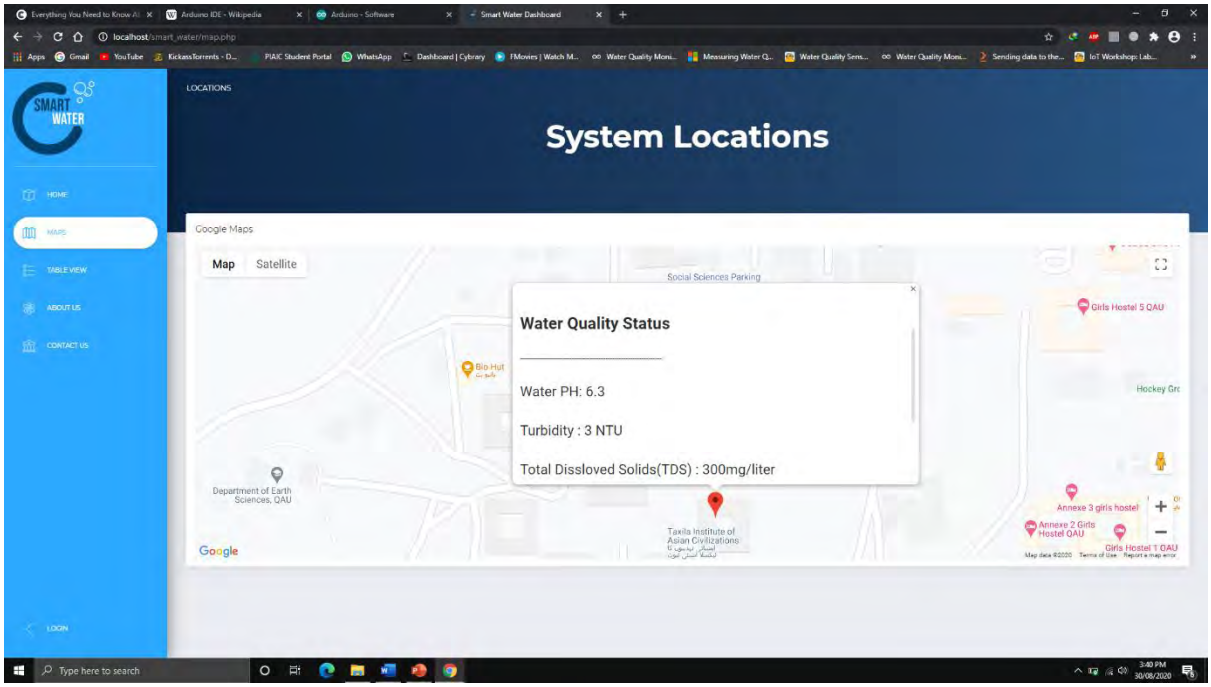

Figure 19 Map View Activity

4.4.4 Table View

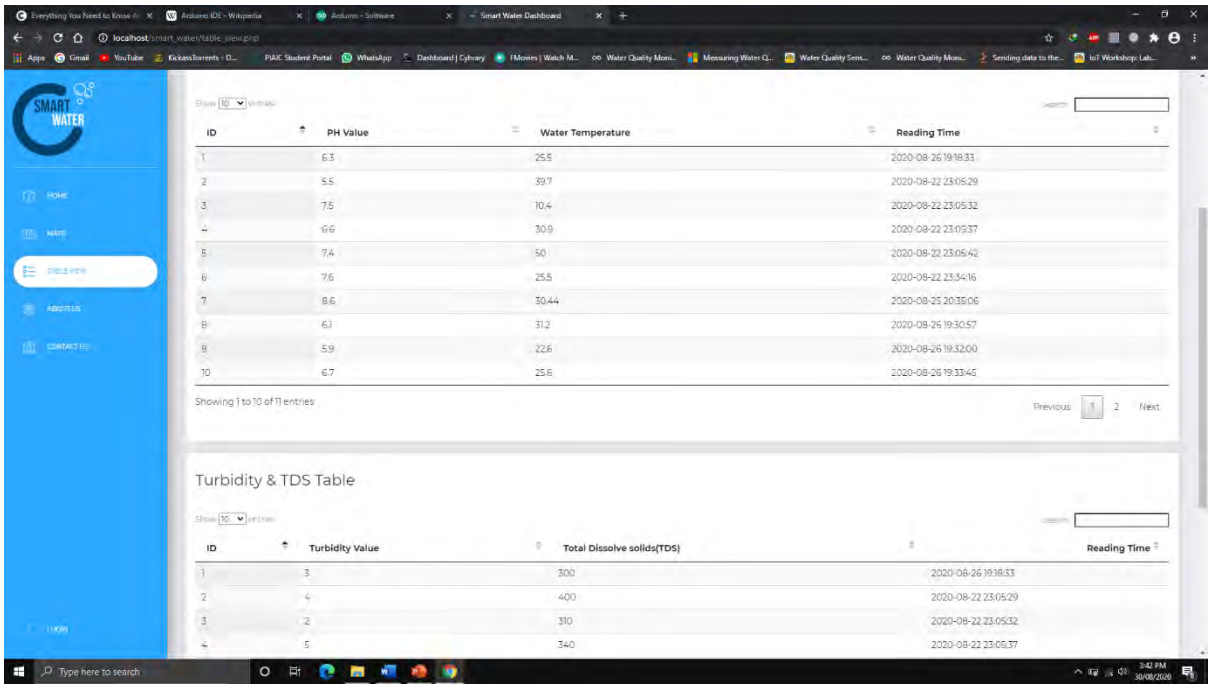

Figure 20 Table View Activity

4.4.5 Contact Us Activity

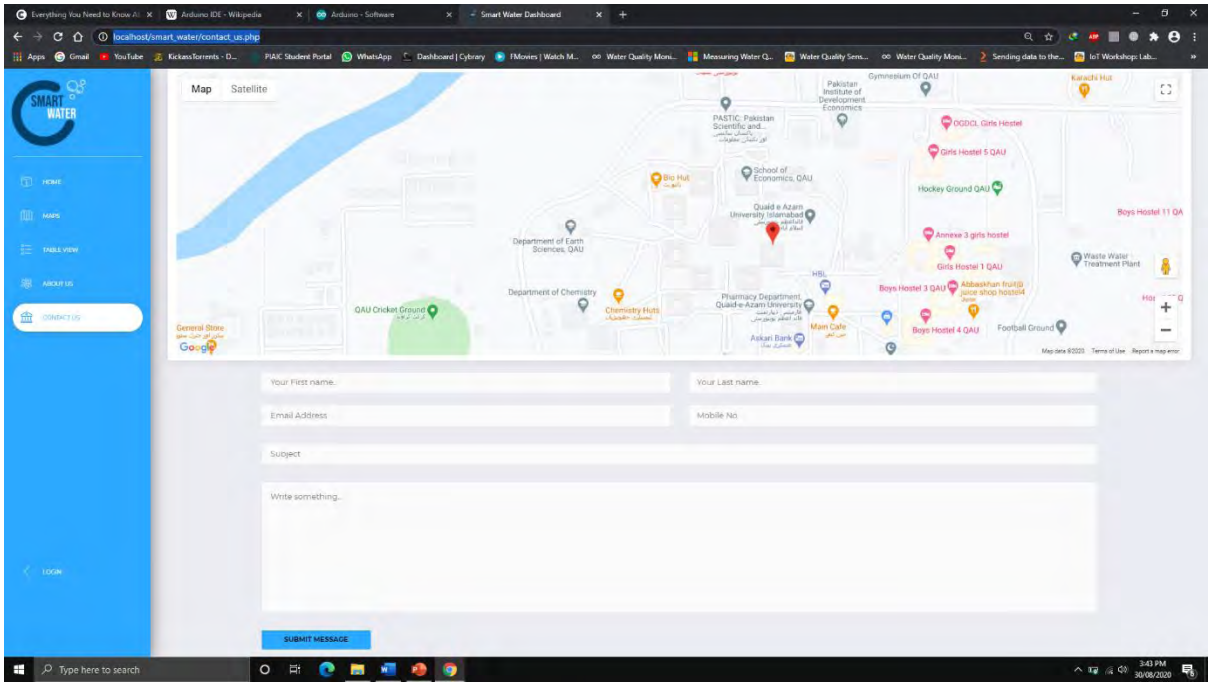

Figure 21 Contact us Activity

4.4.6 Water Quality status on mobile

Figure 22 Water quality status on mobile

Chapter Summary

In this chapter, we have discussed the selected framework for the development of application. The next chapter is about system testing. After implementation, next chapter will be related to the system testing to test the implemented functionality.

Chapter 05

System Testing

5.1 Introduction

The purpose of this document is to provide a structural way to test the system for system testing helps in estimating the testing effort required. Testing is the process of evaluating a system with multiple inputs and scenarios to find whether it satisfies the specified requirements or not. This document will help the tester to find the errors when he is performing the testing of software.

5.1.1 System Overview

System overview focusing on the structural aspects of testing provides an overview of the system in terms of the components that are tested during the unit test.

5.1.2 Test Approach

A test approach is the test strategy implementation of a project, defines how testing would be carried out. I will use acceptance test approach for testing the Project. Acceptance test is a test conducted to determine if the requirements of a specification are met. The main purpose of this test is to evaluate the system's compliance with the business requirements and verify if it has met the required criteria for delivery to end users.

5.2 Test Plan

A test plan outlines the strategy that will be used to test an application, the resources that will be used, and the test environment in which testing will be performed and the time which will spend on testing.

5.2.1 Features to be tested

- Login
- View water quality status
- Download Charts
- Download Sensor’s data
- Send Email
- Ph sensor test with 4.0 and 10.0 PH buffer solution
- Turbidity sensor with clear, muddy water samples
- Temperature sensor with cold normal hot water samples

5.2.2 Testing Tools and Environment

- Laptop/Computer
- Mobile phone
- Internet connection
- Water quality sensors
- Different water Samples

5.3 User Acceptance

Test User acceptance testing is a phase of software testing process. During user acceptance testing, actual software users test the software to make sure it can handle required tasks in real world scenarios, according to specifications. User acceptance testing is one of the final and critical software project procedures that must occur before newly developed software is rolled out to the market.

5.4 Test Cases

Testing of system is recommended every time when new products and deliverables are ready to use. All possible test cases against use cases are as following.

Test case #1: Log In

Test ID	T001
Actor	Admin
Test Description	Admin gets signed in the app.
Setup	Admin should have an account.
Inputs	1. Enter Username 2. Enter Password. 2. Click log in.
Expected Result	User should be logged in.

Observed Result	As expected.
Verdict	Pass

Table 9 Sign in test case

Test case #2: View water quality status

Test ID	T002
Actor	Admin, user
Test Description	Water Quality status displayed on mobile
Setup	Actor have QR scanner application
Inputs	1. Actor opens QR scanner 2. Actor scans QR code
Expected Result	Water quality status should display.
Observed Result	As expected.
Verdict	Pass

Table 10 View water quality status test case

Test case #3: Download charts

Test ID	T003
Actor	Admin
Test Description	Download Real-time charts of water quality parameters PH, Turbidity and Total dissolved solids
Setup	Website is open and actor logged in
Inputs	1. Click on top right corner icon ☰ on charts

	2. From dropdown menu select image format of chart 3. Click download (png, jpg) image
Expected Result	Chart downloads
Observed Result	As expected
Verdict	Pass

Table 11 Download chart test case

Test case #4: Download sensor data

Test ID	T004
Actor	Admin
Test Description	Question is added in selected category list.
Setup	Actor open website and logged in
Inputs	1. Click on top right corner icon ☰ on charts 2. From dropdown menu click download CSV,XLS
Expected Result	CSV,XLS file containing sensor's data downloads
Observed Result	As expected
Verdict	Pass

Table 12 Download sensor data test case

Test case #5: Send Email

Test ID	T004
Actor	Admin
Test Description	Actor wants to send email.
Setup	Actor opens website and logged in

Inputs	1. Click on contact us button. 2. Enter firstname, lastname 3. Enter email,mobile number,subject. 4. Type any message 5. Click submit
Expected Result	Email sent notification display
Observed Result	As expected
Verdict	Pass

Table 13 Download sensor data test case

5.5 Chapter Summary

This chapter specifies all test cases related to this application. These test cases perform one by one to check the functionality of this application. In the next chapter conclusion and future enhancement related to security provider will be discuss.

Chapter 06

Conclusion and Future Enhancements

6.1 Introduction

This section contains overall summary of whole system behavior and the functionalities the system is providing which are briefly described in all previous sections and contains a description about what new advancements which can be done in this field in future.

6.2 Conclusion

The fundamental goal of this project is to ensure the safe drinking of water for students, teacher and other staff of Quaid I Azam University by developing a system that monitors water quality in real-time and allow users to check water quality status quickly just by scanning QR code. Admin is able view and download water quality data generated by the system on charts. In case severe deviation in water quality parameters admin is alerted via SMS notifications.

6.3 Future Enhancements

In future application can be enhanced by introducing the following features: •

- We can include more senor for other water quality parameters.
- We can develop an android/ios application to see water quality status on the phone from anywhere.
- We can add GSM module to the system for more dynamic and unlimited SMS notifications.
- We can also add GPS module to the system to get current location of the system.
- We can expand system functionality by controlling the flow of water using valve control.

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