AGWA: AN AQUACULTURE PH MONITORING AND INVENTORY APPLICATION

DLEAMNOR EURAZE M. CAWALING
MARK ANTHONY E. OCCEÑA

A Special Problem Presented
to the Faculty of the
Division of Physical Sciences and Mathematics
College of Arts and Sciences
University of the Philippines Visayas

In Partial Fulfillment of the Requirements
for the Degree of
Bachelor of Science in Computer Science

July 2023

CERTIFICATE OF APPROVAL

The special problem attached hereto, entitled **“Agwa: An Aquaculture pH Monitoring and Inventory Application”** prepared and submitted by **Dleamnor Euraze M. Cawaling** and **Mark Anthony E. Occeña,** in partial fulfillment of the requirements for the Degree of Bachelor of Science in Computer Science, is hereby accepted.

FRANCIS D. DIMZON, M. Sc.
Member, Thesis Committee
Date Signed: __________________

ARA ABIGAIL AMBITA, M. Sc.
Member, Thesis Committee
Date Signed: __________________

CHRISTI FLORENCE C. CALA-OR, M. Sc.
Adviser, Thesis Committee
Date Signed: __________________

Engr. PERRY NEIL FERNANDEZ M. Sc.
Co-Adviser, Thesis Committee
Date Signed: __________________

Accepted as partial fulfillment of the requirements for the Degree of Bachelor of Science in Computer Science.

ARNEL L. TAMPOS, Ph.D.
Chair, Division of Physical Science and Mathematics
Date Signed: _______________

ABSTRACT

Water quality is crucial for fish's successful growth and survival in aquaculture operations. pH is one significant parameter that affects fish health. However, many aquaculturists neglect to monitor the water pH, leading to fish diseases, slow growth, and fish mortality. Additionally, farmers commonly struggle with managing their farm's inventory, an essential aspect of the aquaculture business for profitability and improvement of aquaculture practices. One way to address these issues is to develop a system that integrates a pH water monitoring device connected to a smartphone application. The device automatically obtains and monitors the pH and sends the real-time sensor readings to the database, which will then be displayed in the application as long as there is an internet connection. This will be less hassle for the user as they don't need to be on-site to monitor the pH. The device can also display the pH readings on its LCD in case the user would like to view the pH level of the water on-site without using the internet. Moreover, the application has an inventory system that lets users record ponds' details, farm activities, and transactions to improve their aquaculture practices. The pH monitoring system was tested by measuring the pH of three buffer solutions with 4, 7, and 10 pH. For the buffer solution with 4pH, the hardware's reading is between 3.39 and 4.24. For 7pH, the range is between 6.937 and 7.227. And for the buffer solution having 10pH, it is 9.951 to 9.981. The results show that the system can accurately measure the pH level of water. Meanwhile, for the inventory, the user can successfully create, edit, and delete records on ponds, farm activities, and transactions.

Keywords: pH monitoring, Arduino Uno, NodeMCU ESP8262, water monitoring system, aquafarm inventory

Acknowledgement

I would like to express my sincere gratitude and deep appreciation to our SP Advisers, Ma'am Christi Florence Cala-or and Sir Perry Neil Fernandez, for their valuable insights and unwavering guidance throughout the entire duration of this project.

I extend my gratitude to the Chemistry Department for graciously allowing us to utilize and borrow buffer solutions in the laboratory to conduct tests on our system.

To my parents, thank you for providing me everything that I needed. I am extremely grateful for the privilege that I have allowing me to have no problems when it comes to finances.

To my sister, thank you for being there especially in times when I needed you the most.

To my thesis partner, Dleam, thank you for being extremely hardworking, patient, and kind. I am extremely grateful that I have gotten to know you and work with you in this special problem. Our SP journey has been fun, and it will definitely be something that I will never forget.

To nong Belt, thank you for your guidance and advice. We genuinely have our sincerest gratitude to you, withthout your help we may would not have been able to succefully finish this special problem.

- Mark

To our SP Advisers, Ma’am Christi Florence Cala-or and Sir Perry Neil Fernandez, my sincere appreciation and heartfelt gratitude for your valuable insights and constant guidance from the beginning to the end of this project.

To the Chemistry Department, thank you for allowing us to use and borrow buffer solutions in the laboratory to test our system.

To my ever-dedicated SP partner, Mark Anthony, thank you for not giving up despite all our hardships this semester. I am forever grateful for the talent you have shared for the success of our project.

To Ria and Flynne, and also to Claire, Hannah, Karmela, Lim, and Pamela, my college life will not be that meaningful without you. I am grateful to each one of you.

To Ava, Diana, Dianne, Iza, Marie, Prima, and Shaira, thank you for being my constant support system since high school. I am blessed to have amazing friends like you.

To my dormmates - Jericho, Aianne, Ava, Anaiah, Cole, Allyson, Ben, and my Aklanon Komsai friends - Earl, Johanna, Mariefher, and Markton, thank you for making college life bearable.

To Kevin Christian Lao, thank you for being my comfort person. I appreciate your constant emotional support and motivation to finish this project.

To my family, thank you for your unwavering love and support. You’re my greatest motivation to finish this degree. Without you, I am not where I am now.

To God, I always have faith in You. I cannot do this without You who strengthens me. Those were not luck; those were miracles and answered prayers from You.

- Dleamnor

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1
INTRODUCTION

1.1 Background and Rationale

Aquaculture, also called aquafarming, is the practice of raising fish, crustaceans, mollusks, algae, and other valuable aquatic organisms in controlled environments (NOAA, 2021). In the Philippines, aquaculture has a long history that involves a wide variety of species and farming techniques in different ecosystems. Most of the production comes from tilapia, seaweed, carp, milkfish, shrimp, oysters, and mussel farming (FAO, 2022).

The aquaculture sector significantly contributes to the Philippines' employment, food security, and foreign currency earnings (FAO, 2022). In 2018, the nation ranked 11th in the world in aquaculture production, producing 826,010 metric tons of aquatic plants, mollusks, crustaceans, and fish. This production was equivalent to 1.8 billion dollars (BFAR, 2021).

The feed-to-conversion ratio (FCR) efficiency of aquaculture offers the most significant potential in addressing food and nutritional concerns since it is lower compared to livestock production.. Since they are buoyant and cold-blooded, The feed conversion ratio (FCR) for aquatic animals like farmed shrimp and fish is between 1.0 and 2.4, which is significantly lower than that of chicken (1.7-2.0), pigs (2.7-5.0), and beef which is between 6.0 to -10.0 (DOST, 2021).

Applying technology in aquaculture typically entails making relatively minor modifications and improvements to an aquafarm. These technologies make it possible to increase the growth rate and overall survival rate of certain species by automating the management of their food, seed, and oxygen levels. It is highly recommended that the aquaculture sector use existing technologies to aid faster and better yields and efficiency in production (P.A. et al., 2021).

According to SEAFDEC (2022), modernized urban fish farms can produce 58 times more than traditional unmodernized farms. Moreover, fish farms that are automated which are powered by artificial intelligence, sensors, big data, and the internet can be seen as the next step for more sustainable production to satisfy future seafood demands.

In this special problem, the researchers aim to create a hardware system connected to a smartphone application. The hardware system will be responsible for monitoring the pH level of the aquafarm's water, and the smartphone application will contain an interface that allows users to check pH levels visually. The application will also contain an inventory system that will aid in monitoring fish farm activities.

1.2 Statement of the Problem

Good water quality is critical in ensuring the maximum growth and survival of the fish for a successful aquaculture operation. Different water quality parameters directly affect the health of the fish, and one of these is the pH. Aquaculturists or fish farmers are unaware of the economic losses in fish farming, which could be avoided by controlling the pH of the water (Mustapha, 2019). They tend to overlook this factor, and they often lack the necessary environmental information to help them identify and avoid problems in their farms.

In the Philippines, most small-scale aquaculturists do not test the pH of the water to check its quality. This can lead to problems such as the occurrence of fish diseases and slow growth and can also lead to a fish kill. Having very low (less than 4.5) or very high (greater than 9.5) pH values can cause problems in the pond. Young fishes are vulnerable to pH levels; they may die at pH levels below 5. Meanwhile, high pH can also harm fish by denaturing cellular membranes (Yokogawa Philippines Inc., n.d.). Also, pH has a critical relationship with ammonia (NH3). Whenever the pH is greater than 9, toxic ammonia will accumulate and can kill the fish. Moreover, high pH can also indicate Cyanobacterial Harmful Algal Blooms (CyanoHABs), a common problem in the pond (Zepernick et al., 2021).

The ideal pH for most fish is between 6.5 and 9. Beyond these values, fish will grow poorly, affecting reproduction (Yokogawa Philippines Inc., n.d.). In aquaculture farming, the fish should achieve their maximum weight during the harvest season to have a good profit. Hence, controlling the pH of the water is essential to maximize the growth of the fish and avoid fish diseases and fill kills.

Moreover, most farmers are not educated enough. They find it challenging to manage their farm's inventory by themselves. Inventory management is an essential part of the aquaculture business. To ensure the business is profitable and to improve aquaculture practices, aquaculturists need to monitor their expenses and income and keep a record of the species they culture (GOIS, 2020).

With the above mentioned, a mobile application could help aquaculturists monitor the water quality and manage their fish farm's inventory needs development. This is why the researchers decided to create an intelligent fish farming application called Agwa that provides the necessary solution to the abovementioned problems and improves their aquaculture practices.

1.3 Significance of the Study

The creation of this mobile application, along with its hardware system, is significant for the following:

- Fish farmers. Having a mobile application that shows the current pH levels of certain bodies of water, such as fish tanks and aquaculture ponds, will allow them to easily monitor their fish farm, particularly the water quality, which will allow them to reduce the number of fish diseases that are brought on by poor water quality while simultaneously raising the amount of fish that are produced by their aquafarm. Furthermore, an inventory system application will allow them to modernize previously paper-based record keeping to manage their farms better since they would have an overview of their aquatic organisms, transactions, and aquafarm activities.
- Future developers. This application could serve as a helpful basis in further creating a more advanced intelligent fish farming application that covers a broader scope.

1.4 Objectives

The general objective of the study is to develop a mobile application that integrates a pH level monitoring and notification system, and fish farm inventory to improve aquaculture practices.

Specifically, this study aims to:

1. To develop a pH level monitoring and notification system wherein:
    - A pH sensor (PH-4502C Liquid pH sensor with E201-BNC Electrode for Arduino) is used to measure the water's ph level;
    - Users can set a normal ph level depending on the type of fish that they have; and
    - Users are notified through a mobile application if the pH level is higher or lower than normal.
2. To develop an inventory system inside a mobile application to store information about a pond's data, the fish farmer's financial transactions, and their tasks. Specifically, it must have the following features:
    - A database that stores the fish pond's data such as the type of fish, the date that the fish was released to the pond, number of fishes released, age, average target weight (based on the age), a target date of harvest, and the total weight of fish harvested.
    - Keep track of the transactions to monitor the farmer's expenses and income.
    - A task tracker to help the farmer monitor fish farm activities.

1.5 Scope and Limitations

This mobile application primarily focuses on providing support for our fish farmers by providing them with a platform wherein it simplifies and digitizes data entry and record keeping in the fish farm. The application will also integrate a technology that could monitor the water quality by testing only the pH level of water. Water quality parameters such as temperature, oxygen level, water level, and salinity can also be monitored to ensure that the fishes will have a better water quality, however, this study only focuses on monitoring the water quality by testing the water's pH level.

The application does not provide the normal pH level for different fish types. The users are the ones who will enter the details about the fish type and will set the normal pH level of the fish. This is because different kinds of fish require different levels of pH. However a default normal pH values will be set ranging from 6.5 and 9, which is the optimum pH for most fish.

Agwa is only connected to one pH sensor and is only able to monitor the pH level of one body of water at a time and . The pH sensor in the hardware system is able to measure the usual types of water such as salt water, fresh water, and pond water. The data within the inventory system will be based on the user's manual inputs. Furthermore, the application is only supported on android devices with a minimum android SDK version of 21 or Android 5.0 Lollipop.

CHAPTER 2
REVIEW OF RELATED LITERATURE

This chapter presents an overview and discussion of existing research projects and literature related to this study to gain relevant information that could help the researchers determine the right development tools and methodology for the project's development.

2.1 Measuring pH level

A pH is one of the variables that must be measured to ensure a healthy pond and achieve high fish yields; this is according to a study by Anita and Pooja (2013). The pH level can be measured using litmus paper, commonly used in aquariums. However, electronic pH meters are preferred for scientific purposes due to their accuracy and reliability (Aride et al., 2004). Also, in a study conducted by Engr. Dipay (2021), using pH meters can make the process of water monitoring more enhanced, faster, easier. In this study, a pH meter/sensor is used to determine the water's pH level.

2.1.1 pH Sensor

A pH sensor is an instrument used to measure the pH or hydrogen-ion concentration in a water-based solution to determine its acidity or alkalinity. It is sometimes referred to as a "potentiometric pH meter" as it calculates the difference in the electrical potential between a reference electrode and a pH electrode (Labs Nova, 2021). Harun et al. (2018) used the Analog pH Meter Kit SKU: SEN0169 to measure the pH level of the fish pond. The instrument has a 5V power module and can measure the entire range of acidity to the alkalinity of 0 to 14 pH. Moreover, it can stand the temperature range from 0 to 60 ℃. Also, its accuracy is +- 0.1 pH (25 ℃), and its response time is less than or equal to negative 1 minute.

On the other hand, an analog pH sensor kit: SEN0169, can also be used to determine the pH level. Nasution et al. (2020) analyzed the water using the SENO161 pH sensor for water in goldfish ponds. Based on the results, the percent accuracy of this instrument is +- 98.39% and +- 99.07%, as they tested it using two sensor nodes. This instrument has almost the exact specifications as the SEN0169. However, SEN0169 is much better as it supports long-firing operation, meaning that it can be used for continuous testing, unlike the SEN0161, which cannot be immersed in water for continuous testing. Also, SEN0169 has a longer life span than the other. It can last for two years when put to continuous testing in 25 ℃ pure water, while the SEN0161 only lasts for six months. SEN0169 is also waterproof and can withstand strong acid and alkali environments. SEN0161's whole probe cannot be immersed in the water (DFRobot, 2017).

Similarly, any available analog pH sensor will be used in this study to monitor the pH level of the fish pond because they are low-cost, have practical features, and are specifically designed for Arduino controllers. The analog pH sensor kit will be installed in the fish pond and connected to an Arduino board.

2.2 Water Quality Monitoring and Alarm System

There are different kinds of monitoring and alarm systems depending on their purpose. Some monitoring and alarm systems are used for security purposes, while other vehicles, such as vehicle accident detection systems, are used for safety purposes. Monitoring and alarm systems help detect and prevent failures of devices, applications, services, and businesses (Pandora FMS, 2022). Internet of Things (IoT) technology is usually integrated into monitoring and alarm systems (Nocheski and Naumoski, 2018). With the use of technology, monitoring a thing can make humans work less.

The water quality monitoring system is developed to observe the water quality in real time through IoT technology (Pramana et al., 2021). Some monitoring systems have an alarm system that alerts the user if the water quality is beyond normal; this can help prevent more significant problems that result from poor water quality (Wang, 2022). In the study of Pramana et al. (2021) which focuses on the remote water quality monitoring and early warning system, they use IoT technology to monitor the water quality. Internet-based smartphone applications are also utilized to monitor water quality data.

2.3 Database Management Systems

According to Geppert and Dittrich (2001), "database management systems" (DBMS) refer to software systems that are used in order to support software applications by allowing them to store, model, retrieve, create queries, and manipulate data. DBMS are ubiquitous in every piece of software we use daily, as they are always required for software applications to store, retrieve, and manipulate long-term data.

One of the most common types of a database is the relational database (RDBMS); it mainly focuses on how data are related (IBM, 2010). RDBMSs are derived from the relational model, meaning they are an easy-to-understand method of representing data through tables. In this type of database, each table row is a record associated with a distinct ID referred to as the key. On the other hand, the columns hold the data's attributes, allowing developers to easily create and manage relationships among different data points (Oracle, 2022).

2.3.1 Hosting Services for Database Management

Baker (2022) defines a *hosting web service* as a way for big hosting companies to allow clients to put their websites or web applications on the Internet. Hosting services grant all the resources and facilities needed to create and maintain a functioning website. It makes websites easily accessible across several platforms, such as desktop computers, mobile phones, and tablet computers.

Most websites or web applications we see today are made up of many files, such as texts, videos, images, and the website's code. These files must be stored on specialized machines known as servers. The one who provides the hosting service is responsible for maintaining, configuring, and running these physical servers so that people can rent a portion of their storage to store files for their websites. Other hosting service providers offer extra support like security, increased website performance, and backup (Amazon, 2022).

2.3.2 Hosting Services for Microcontrollers and Mobile Applications

One beneficial hosting service provider is *Firebase* which allows hardware such as microcontrollers to communicate with software such as mobile applications. Firebase was created in 2011 by Firebase, Inc. and is now owned and continually updated by Google as of 2014. Firebase is more than just a hosting service provider; it offers 18 different product features that almost 1.5 million apps utilize. It is an app development platform that is the ultimate support for developing websites, applications, and games (Firebase, 2022).

2.4 Inventory Management Applications

Singh and Verma (2018) argue that businesses must easily control, manage, and monitor their inventory. In today's modern world, business transactions can take place worldwide and in various places, which is why effective inventory management is essential to a business's long-term survival and viability. The manual inputting, counting and monitoring of inventory can be impractical by today's standards.

In a thesis submitted by Abdul Aleem (2013), an inventory system was developed and proposed for a retail store that still used manual inventory management. The application that was developed was an offline window-based desktop software. Some of the objectives of his thesis were to create an "update," "add," and "delete" product within the store's stock. Additionally, the application generated a weekly report on inventory and sales activities. Furthermore, it was also able to save a soft copy of the receipt of customers each time they purchased to reference customers when needed. The methodology involved was the Rapid Application Development (RAD) method. This adaptive and flexible software development model primarily relies on quick feedback and prototyping with less focus on being specific when it comes to planning. The paper recommends that future developers should be able to improve the inventory management application by creating a connection with the retail store and the supplier and then using data mining to discover patterns in the sales.

2.5 Applications Developed Specifically for Farming

A paper titled "Using a smartphone app to support participatory agroforestry planning in Central America" discusses the development of android mobile application to help in agroforestry planning (Casanoves et al, 2015). The app was developed so that many farmers must be aware of silvicultural practices, which could greatly help increase timber production. The application can be used by any machine that has Android OS 4.0 or later versions. Some of the main functionalities of the application were to allow users to input tree attributes such as species name, height, diameter, circumference, stem form, and tree health. The data inputted to the application and outputted by the application is saved on a computer as a .csv file.

2.6 Applications Related to Aquaculture

Single Spark The Netherlands (2020) released a mobile application in the Google Play Store named "ရွှေငါး - Shwe Ngar" or "Goldfish", it is a mobile application that allows fish farmers to be connected to aquaculture information. USAID funded it, which was initially developed by WorldFish during the pandemic specifically for the people of Myanmar, as some fish farmers had limited access to extra services because of the lockdown. The mobile application offers fish farmers up-to-date information on fish health, aquaculture technologies, how to feed and stock fish, and best practices for nutrition, water, and sanitation. Additionally, to boost the fisheries sector of Myanmar, the app allows fish farmers to be connected to traders and suppliers of aquacultured products.

2.6.1 Aquaculture Technology Providers

Currently, some companies specifically provide services in aquaculture; one such company is *aquaManager* (2022), based in Greece. The company offers engineering and scientific expertise in aquaculture and provides various aquaculture management software systems. One of the software systems that they offer is the *aM I-MAINT. This maintenance software* is used to organize, track, plan, and analyze tasks required for aquaculture teams to complete so that they can manage activities related to the maintenance of the whole aquaculture farm. The software also offers data analysis related to fish production, which could be immensely helpful in aquaculture hatchery facilities. Another software they could provide is a mobile or desktop application specifically made for fish growth named *Grow Out*. This application aids in the growth of fish by continuously monitoring fish behavior based on real-time data: saving the daily activities of fish, reporting data in graphical or tabular formats, automatically detecting problems in fish growth as soon as they arise, evaluating fish feed suppliers, identifying the best feeding practices, and suggesting optimized feeding tables.

2.7 pH Sensing Systems

Cao et al. (2021) developed a wireless pH sensor system that focuses on monitoring the freshness of a frozen fish's meat. Figure 2.1 shows the actual block diagram of their system found in their paper. It is composed of a pH electrode; a sensor tag; a circuit known as a summing amplifier; and a wireless module. The pH sensor is connected to an inverting amplifier, which is responsible for performing operations on the pH signals sent by the pH sensing electrode to filter out the signals. The filtered signal is then sent wirelessly to the TRF7970A module which is responsible for reading and writing data, which then goes to the MSP432F5529 which is a signal processing module connected to a power supply.

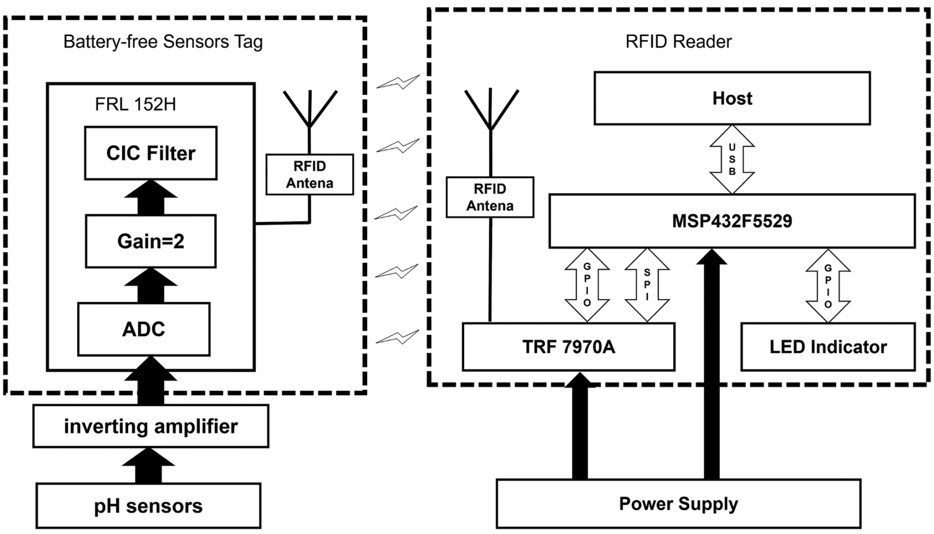


Figure. 2.1 Block diagram of a wireless pH sensor system (Cao et al., 2021)

2.8 Existing Fish Pond Monitoring Systems

An "Automatic Water Monitoring System For Tilapia Culture with Mobile Application" is a system that automatically monitors the temperature and potential hydrogen (pH) level of the fish ponds. In the said study, the researcher found that the pH meter is the most suitable water attribute in the water monitoring system. A pH meter is efficient in improving water monitoring practices to make the process quicker and easier, which can also be used to help maintain the temperature of the water (Dipay, 2021).

The automated features of the pond along with its fish monitoring in real-time were created using an Arduino by Harun et al. (2018) in Malacca, Malaysia. They integrated dissolved oxygen (DO) and pH sensors while also integrated it with the water and temperature level module. The user can receive the readings from these sensors via a domestic Wi-Fi network to an online Google spreadsheet at predetermined intervals. The system consisted of relay frames, a display system, and an Arduino board.

2.9 Synthesis

The researchers aim to create a water quality monitoring device connected to a smartphone application to help aquaculturists prevent problems related to poor water quality. Moreover, they want to help the farmers manage their farm's inventory to improve aquaculture practices by providing an inventory within a smartphone application.

Several projects and studies discussed in this chapter emphasized the importance of measuring the pH level to maintain a healthy pond and achieve high fish yields. While litmus paper is commonly used to test water pH, electronic pH meters are preferred for scientific purposes because they are accurate and reliable. The pH meter or sensor, or potentiometric pH meter, calculates the difference in electrical potential between a reference electrode and a pH electrode. Analog pH meters, such as SENO169, have been used in previous research due to their wide range of acidity to alkalinity measurement, temperature tolerance, and accuracy.

Water quality monitoring and alarm systems are crucial in detecting and preventing issues related to poor water quality, such as fish diseases, slow growth, and fish kill. These systems, often integrated with Internet of Things (IoT) technology, enable real-time observation and early warning capabilities. Internet-based smartphone applications are utilized to monitor water quality.

Moreover, inventory management applications are essential for businesses to control and monitor their inventory effectively. Manual inventory management can be impractical, and software applications can streamline the process.

Applications developed explicitly for farming and aquaculture provide valuable support for farmers. Smartphone applications have been designed to assist in aquaculture management and maintenance. However, applications that can monitor the water quality and alert the user if the water quality is critical for fish survival and, at the same time, provide an inventory platform for aquaculturists still need to be developed. Water monitoring systems and farm inventory are usually separate systems; in this study, the researchers aim to build a system that integrates water monitoring and alarm system and farm inventory. The pH monitoring device is responsible for monitoring the pH of the water, and the hardware is connected to a smartphone application that contains an interface that allows users to visually check pH levels anywhere they are as long as they have an internet connection. The user is then notified if the pH of the water is not in the normal range for the fish to be in the best environment to survive, be healthy, and maximize their growth. Additionally, the application contains an inventory system that aids in monitoring fish farm activities to improve aquaculture practices.

CHAPTER 3

MATERIALS AND METHODS

This study presents a functional and user-friendly microcontroller based pH water monitoring system that is connected to a smartphone application. The system will enable the user to remotely monitor the water pH in ponds to ensure the survival and maximum growth of the fishes. Additionally, the application contains an inventory system that aims to digitalize the record keeping of users. Materials and methods used in the development are discussed in this chapter.

3.1 Development Tools and Software Requirements

3.1.1 Hardware Components

Microcontroller (Arduino Uno R3)

A microcontroller is usually made up of different parts such as the power source port or jack, pins, processors, and other components. The Arduino Uno R3 microcontroller will serve as the core of the pH water monitoring hardware system. An Arduino is an open-source electronics platform developed for easy-to-use hardware and software. The Arduino boards can read inputs from the sensors and turn them into an output. An Arduino programming language is used to give instructions to the board (Arduino, 2022).

pH Sensor

A pH sensor, specifically an analog pH sensor kit, is used to measure the pH level of the water in the pond. It is specifically designed for Arduino controllers and is low-cost compared to other pH sensors (DFRobot, 2017). In this project, a PH-450C Liquid PH sensor with E201-BNC Electrode is used as the pH sensor.

WiFi Module (ESP8266-12E/NodeMCU)

A WiFi Module connects the microcontroller to the mobile application. It is mainly utilized for IoT-based embedded applications development to access the WiFi network (Agarwal, 2022). In this project, NodeMCU V3 ESP8266-12E will be used. It incorporates a TCP/IP protocol stack to facilitate multiple connections from clients, with a maximum limit of five. It operates on a single band 802.11 b/g/n wireless technology, utilizing a 2.4Ghz frequency. The device is designed to interface and function at a voltage of 3.3V (Makerlab Electronics, n.d.). .

Power Source (Powerbank)

When powering an IoT device that monitors the pH level, a power source such as a power bank, battery, or electric outlet is needed. In this study, a power bank can be an option to power the device to make the system portable. Nevertheless, the IoT device can also be connected to an electrical outlet if the user opts to plug it into it.

Smartphone

A smartphone is a cellular device with advanced processing capabilities (Merriam-Webster, 2022). The system is developed for and tested using a smartphone, particularly an Android operating system with Android version 8.1.0, and 3GB RAM.

Laptop

The laptop is a portable computer with built-in batteries. Hence it can be used on the go without needing a power outlet (Techopedia, 2017). The system is developed on a laptop with a Core i3 CPU or higher and a minimum of 4GB RAM.

3.1.2 Software Components

Arduino Software Integrated Development (IDE)

Arduino IDE is a development environment for Arduino. It connects to the Arduino hardware to upload programs and communicate with them. It is written in Java and is compatible with Windows, macOS, and Linux operating systems (Arduino, 2023). In this project, Arduino IDE is used to upload program codes to Arduino Uno R3, and the NodeMCU.

Trello

Trello is a web-based Kanban-inspired project management app that allows one to organize, sort, plan and collaborate in a visually appealing way. The managers and team members can see the project's progress, set work to be done and the person assigned to it, and then mark the tasks completed (Trello, 2022). In this study, Trello is utilized to organize and track the tasks.

Figma

Figma is a free collaborative web application for all graphic design work, such as wireframing websites, designing app interfaces, prototyping designs, creating diagrams, and many others (Perera, 2020). This study uses this application to create a wireframe of the app, diagrams, and prototyping design.

Integrated Development Environment (Android Studio)

Android Studio is an integrated development environment designed specifically for Android development. It offers features that increase productivity while building applications. Moreover, Android Studio supports an integrated IDE experience for Flutter, the programming language used to build the application (Google Developers, 2022).

GitHub

GitHub is a web-based platform that allows users to share and collaborate on code. Developers and organizations widely use it to host and manage their projects, including features such as version control, bug tracking, and project management tools (Kinsta, 2022).

Flutter

Flutter is a mobile app development framework made by Google that developers widely use to build and deploy cross-platform applications quickly. It allows developers to build web, mobile, and desktop applications from a single codebase. It uses the Dart programming language and includes a rich set of customizable widgets, tools, and APIs to create high-performance and visually attractive applications (Flutter, 2022).

Firebase

Firebase is a software framework created by Google with the purpose of aiding the development of mobile and web applications. It offers a range of functionalities, such as a real-time database, cloud messaging, crash reporting, and analytics. Firebase is specifically designed to simplify the process of building and maintaining high-quality applications (Firebase, n.d.). In this paper, Firebase serves as the bridge for data transfer between the hardware system and mobile application. The pH measurements from the hardware is sent to the Firebase Realtime Database and will be retrieved by the mobile application. Additionally, Firebase will be used as the inventory system's backend database.

3.1.3 Software Requirements

Functional Requirements

1. Show the pH levels of water in a certain pond.
    - The application is connected to a sensor.
    - The system shows the exact numerical real-time measurement of the pH levels of the pond
    - The system shows to the users if the pH level is normal or critical.

2. Provide an inventory management system for aquatic organisms present in a particular pond.

   - The application shall display a list of ponds and it includes other details such as the pond id, aquatic species in the pond, the birthdate of the species, initial quantity, target weight, target date of harvest, and the required range of the normal pH level.
   - The application shall allow the user to add data to the list so they can input their data manually.
   - The application should allow the user to edit and delete data in the list.

3. Allow financial transactions to be tracked.

   - The application displays a list that includes transaction description, date of transaction, amount, and transaction type whether it is an expense or revenue.
   - The application shall allow the user to add data to the list so they can manually input their transactions.
   - The application should allow the user to edit and delete data in the list.

4. Provide a task tracker.

   - The application displays a list of tasks
   - The application allows the users to add certain tasks, by allowing them to input a string of words to the list.
   - The application allows the users to edit and delete existing tasks.
   - The application shall allow the users to set a deadline for these tasks.

External Interface Requirements

User Interfaces

Since a mobile application is to be developed in this research, the user interface of this system will only be available to android devices that run Android 4.1 and later versions. The front end of the system will be developed using Flutter in Android Studio, while the back end of the software will be developed with the use of Firebase.

Hardware Interfaces

The user will be required to use an android device for this system's hardware interface. On the other hand, in order to develop this system, an Arduino Board, pH Sensor, Wifi Module, 16x2 LCD, and a power bank or any electrical outlet will be required.

Software Interfaces

The Arduino Board will send data to the mobile application through the use of Firebase. During development, first, Trello will be used for project management. Second, Figma will then be used for prototyping. Third, Android Studio will be used to write the Flutter code that will be used to create the system. Lastly, Github will be used in order to organize the researchers' code.

Application Features

1. The application should contain two main pages: "Home", and "Inventory".
2. The application should display a "pH level" section on the home page.
3. The application should display a "Pending tasks" section on the home page.
4. The application should display a "Ponds", "Transactions", and "Tasks", section on the inventory page.

Nonfunctional Requirements

1. Each page in the application should load within 3 seconds.
2. The design of the user interface should feel easy and natural to use.
3. The texts and icons used in the application should be easy to understand.
4. The system should be reliable and can be used continuously for more than 5 days.
5. The system should be able to store and manage sufficiently large amounts of data.

3.3 Methodology

3.3.1 Agile Methodology

In this study, the agile methodology is used in software development. Agile methods are known for their incremental way of developing software; it focuses on fast-paced small releases of working software that composes certain parts of the whole software system (Sommerville, 2011). Since the agile method focuses on multiple iterations and output release, a more stable product will be created because iterated releases would mean earlier detection of errors, efficient testing, and a better capacity to adapt to required changes (Cockburn, 2006).

The researchers used a more specific agile method, the Scrum method. This specific method is helpful in project management as it revolves around multiple sprints, which are time blocks that involve creating working products (Sommerville, 2011). Within the duration of this thesis, the researchers used *Trello* as the scrum board, and the first thing they did was develop a draft version of the application's prototype using *Figma*.

3.4 Diagrams

Theoretical Framework

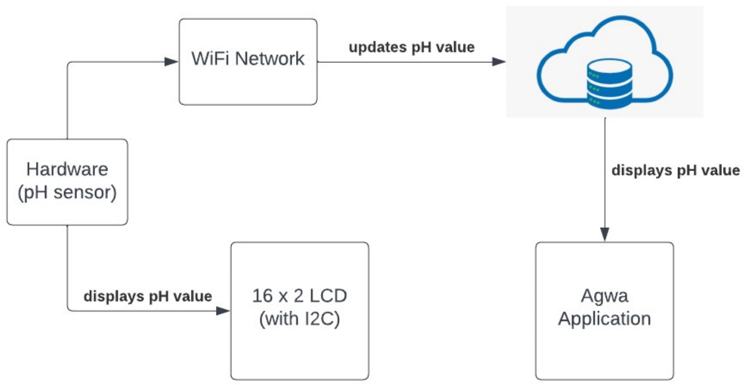


Figure 3.1 Theoretical Framework of pH monitoring system

Figure 3.1 shows the theoretical framework on how the pH monitoring system works. In the diagram above, the hardware system reads the pH value through the use of a pH sensor. The sensor reading will then be displayed to a built-in LCD so that the user can view the pH reading on-site without the use of an Internet. Also, the hardware is connected to a WiFi network to send the pH readings to the cloud. The application will then fetch the data from the cloud and display it on the app to be viewed by the user anywhere in the world.

Use Case Diagram

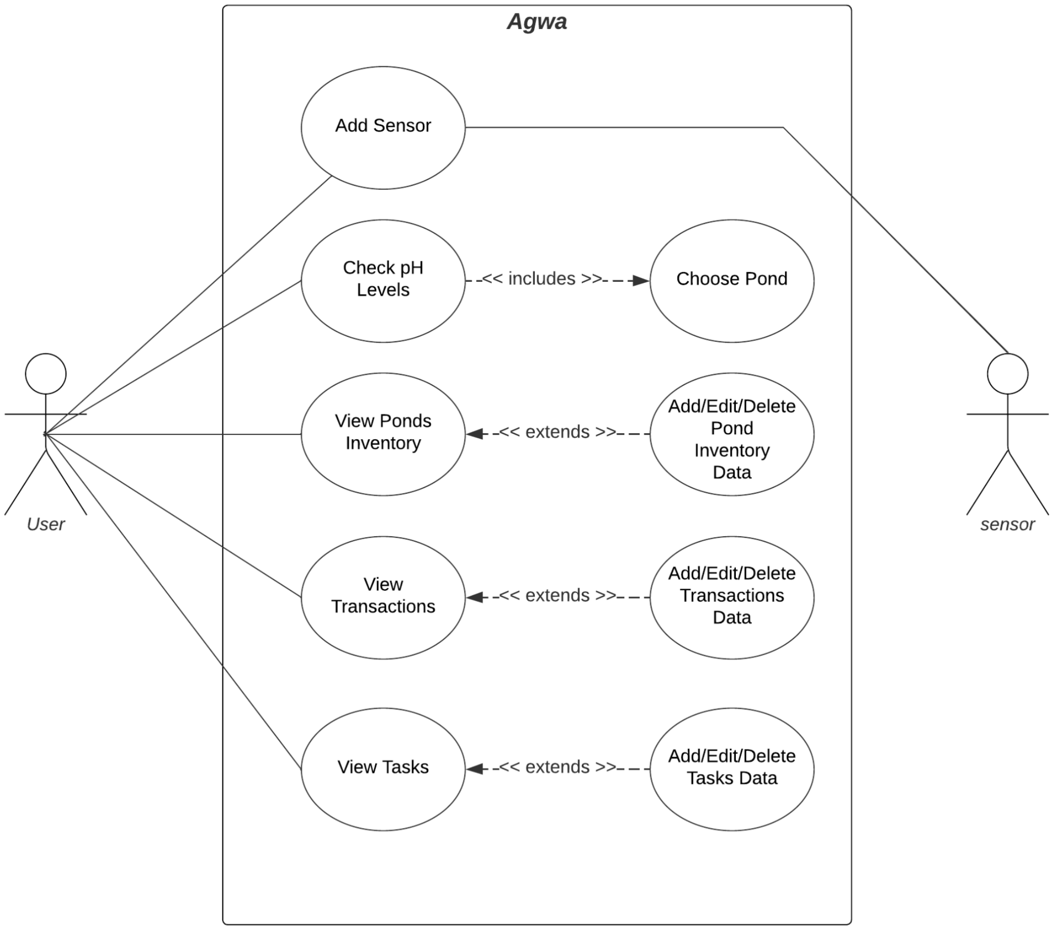


Figure 3.2 Use Case Diagram

Shown in Figure 3.1, is the mobile application's use case diagram. The diagram shows how the users will interact with the application given specific course of actions. The user here will be typically an aquaculture farmer, who will be navigating and providing input to the application. As can be seen in the diagram, the first thing that a user could do is to add or connect a pH sensor to the application. Then when they want to check the pH levels of different ponds, the user would be required to choose a pond to be tested. If ever the user decides to check the inventory of the pond, check transaction, or check tasks, they would have the option to add, edit or delete data within that specific page.

Architecture Diagram

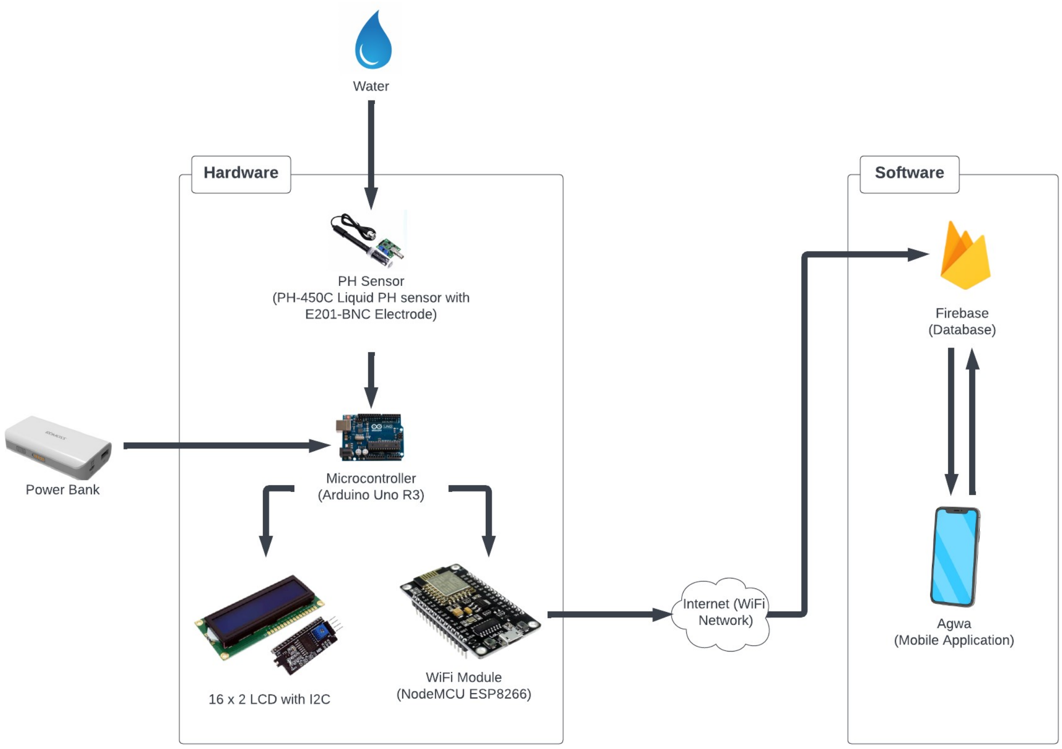


Figure 3.3 Architecture Diagram

Figure 3.3 shows the Architecture Diagram of the hardware system and software system. It shows that the pH Sensor (PH-450C Liquid PH sensor with E201-BNC Electrode) is responsible for detecting the pH level of water, it then sends the data to the Microcontroller (Arduino Uno R3) which is powered by a Power Bank. The pH data is sent to the LCD to display the pH level value, and it will also be sent to the WiFi Module (WiFi Module NodeMCU ESP8266). The WiFi Module will then be responsible for sending the pH data to the internet, which will then be stored in Firebase which serves as the mobile application's backend database. The mobile application will be able to read and write data in the database, in which pH data stored in the database will be read and displayed by the mobile application and inventory data will be created by user input.

Entity Relationship Diagram

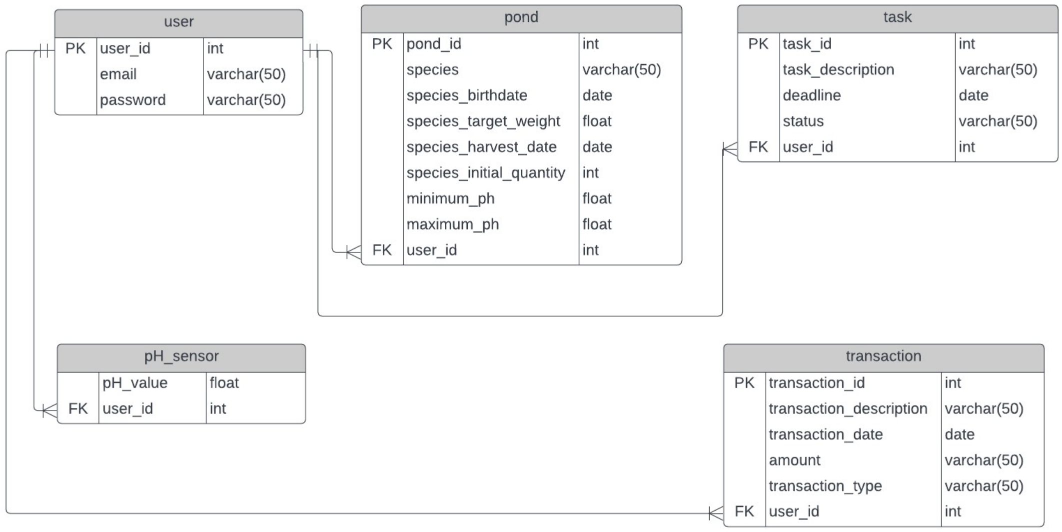


Figure 3.4 Entity Relationship Diagram

The database of the application is composed of five tables: **user**, **pond**, **task**, **pH_sensor**, and **transaction**.

The "**user**" table contains the primary key *user_id* - the user's reference number, which has no NULL value and should be auto-incremented. The table also includes attributes such as the *first_name*, *last_name*, *address*, *email*, and *phone_number*.

The "**pond**" table contains the primary key *pond_id* as the unique identifier of the pond, *species*, *species_birthdate*, *species_target_weight*, *target_harvest_date*, *species_initial_quantity*, *pH_level_range*, and it has a foreign key *user_id*.

The "**task**" table contains the primary key *task_id*, then it also includes fields such as *task_description*, *deadline*, *status* which can have a value of done or pending, as well as the *user_id* as the foreign key.

The "**transaction**" table has a primary key *transaction_id,* and other fields such as the *transaction_description*, *transaction_date*, *amount* to identify the amount of revenue or expenses, *transaction_type*, and *user_id* as a foreign key.

The **“pH_sensor”** table has a foreign key *user_id* and *pH_value* as another field to store the pH readings from the sensor. The pH value is added to the database of the inventory system. However, previous sensor readings cannot be accessed since the pH value is being updated or changing in real-time.

3.5 Total Cost of Ownership (TCO)

The development of the system in this study entailed the following financial expenses presented in Table X.

Table 3.1 Financial Expenditures

Component	Price (in PHP)
Arduino Uno	Php 500.00
pH sensor	Php 1000.00
WiFi Module	Php 160.00
Breadboard	Php 65.00
	Total: Php 1725.00

Table 3.1 shows that the development of the system required an estimated total of Php 1725.00, this shows that the system is quite costly for commercial use. A thorough financial analysis can be conducted to assess the return on investment (ROI) tailored to a single fish farm to further examine the financial component in order to determine whether implementing the system would lead to a financial loss or profit for its users.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 pH Monitoring Device

The pH monitoring device in Figure 4.1 was made to measure the pH level of the water. Arduino Uno was used as the microcontroller connecting the hardware components such as the NodeMCU ESP8266, 16x2 LCD, and the PH-450C Liquid pH sensor with E201-BC Electrode (see Figure 4.2). The connections of the hardware components are presented in the schematic diagram in Figure 4.3. Arduino Uno and NodeMCU should be connected to the power supply to power the pH monitoring device. The program uploaded in the Arduino enables reading the pH sensor data and displaying it on a 16x2 LCD. Figure 4.4, shows the display of the LCD wherein the pH reading can be seen along with the classification if it is Acidic, Normal or Basic. pH value with 6.5 to 9 are considered Normal, while pH value less than 6.5 is classified as Acidic. Meanwhile, pH value higher than 9 is classified as Basic (see Figure 4.5). The pH readings are then sent to the NodeMCU that handles the WiFi connectivity and communication with the Firebase Realtime Database.

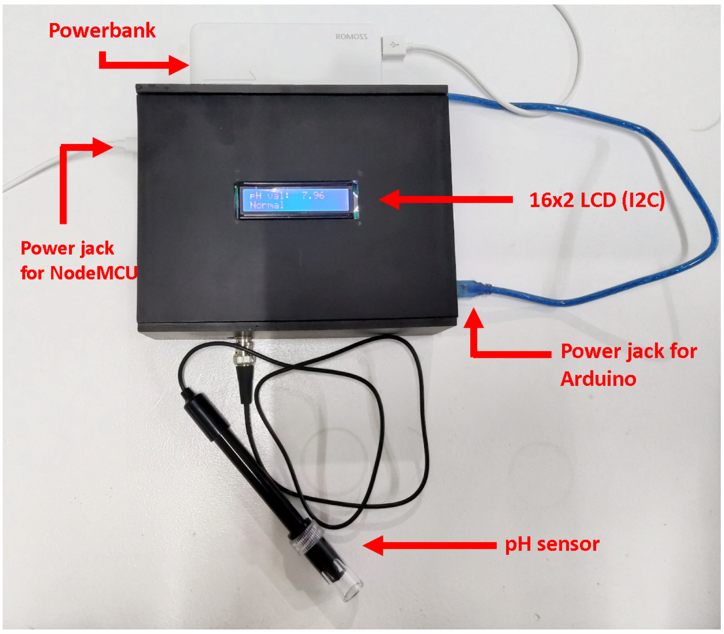


Figure 4.1 External Interface of pH Monitoring Device

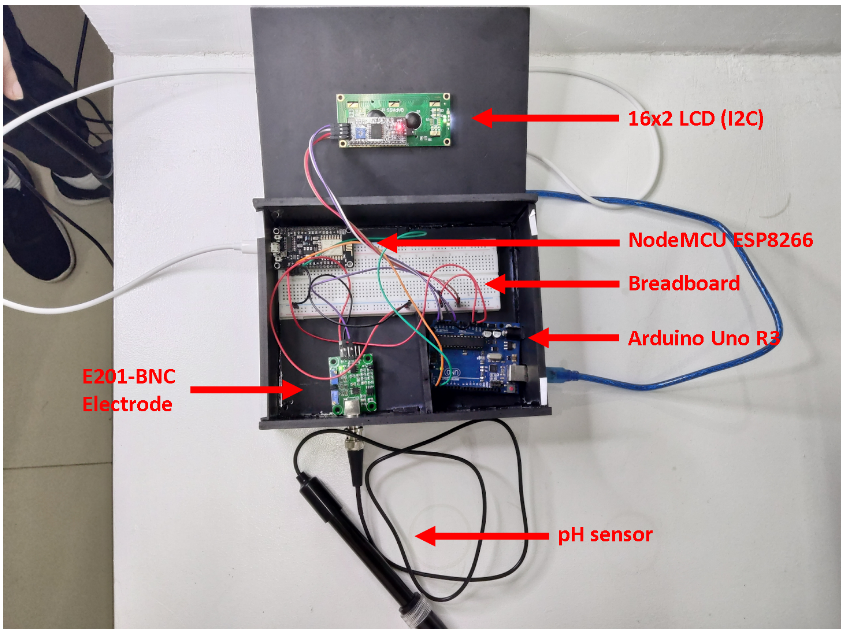


Figure 4.2 Internal Interface of pH Monitoring Device

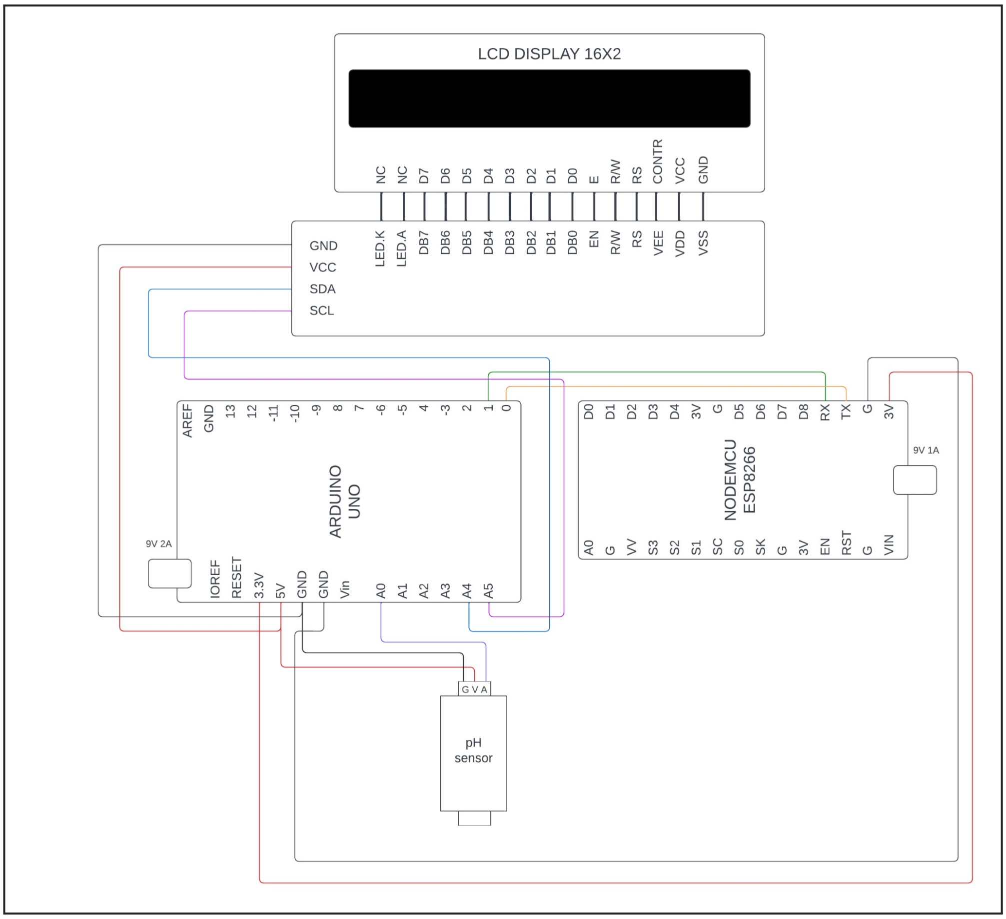


Figure 4.3 Schematic Diagram of the pH Monitoring Device

Figure 4.4 LCD Display

```
void displaypHValueLCD(float pH_value){
  lcd.setCursor(0,0);
  lcd.print("pH val: ");
  lcd.setCursor(9,0);
  lcd.print(pH_value);

  //display
  if(pH_value>=6.5 && pH_value<=9.0){
    lcd.setCursor(0,1);
    lcd.print("Normal");
  }else if(pH_value<6.5){
    lcd.setCursor(0,1);
    lcd.print("Acidic");
  }else{
    lcd.setCursor(0,1);
    lcd.print("Basic ");
  }
  Serial.print("pH Value: ");
  Serial.println(pH_value);
}
```

Figure 4.5 Arduino Code to display data on the LCD

4.1.1 Accuracy Test of pH Sensor

The calibration and testing of the pH sensor were done at the University of the Philippines Visayas Miagao Campus at the Chemistry Laboratory of the College of Arts and Sciences, supervised by a Laboratory Technician. Appendix K shows the written request letter sent to the Department of Chemistry Chair. The Chemistry Department provided three buffer solutions with pH values of 4, 7, and 10, as shown in Figures 4.7 - 4.9.

The pH sensor outputs an analog value. Hence, it is necessary to convert the analog value to a voltage in the Arduino program. As seen in

Figure 4.6, the program takes 6 sample analog values to minimize errors in the readings and stores them in an array, then using this formula *float volt = (float)avgval * 5.0/1024/6*, analog values are converted to a voltage and then get their average. After that, the actual pH value is calculated using the formula *pH_actual= -5.70 * volt + calibration_value*. The calibration value equals 21.34 + n, wherein n is to be manipulated to make the readings accurate.

```
//calculate the average of a 6 centre sample Analog values
float calibration_value = 21.34 + 1.08;
avgval=0;
for(int i=2;i<8;i++)
  avgval+=buffer_arr[i];
  float volt=(float)avgval*5.0/1024/6;
  ph_act = -5.70 * volt + calibration_value;

return ph_act;
```

Figure 4.6 Code snippet of Arduino program that reads the pH

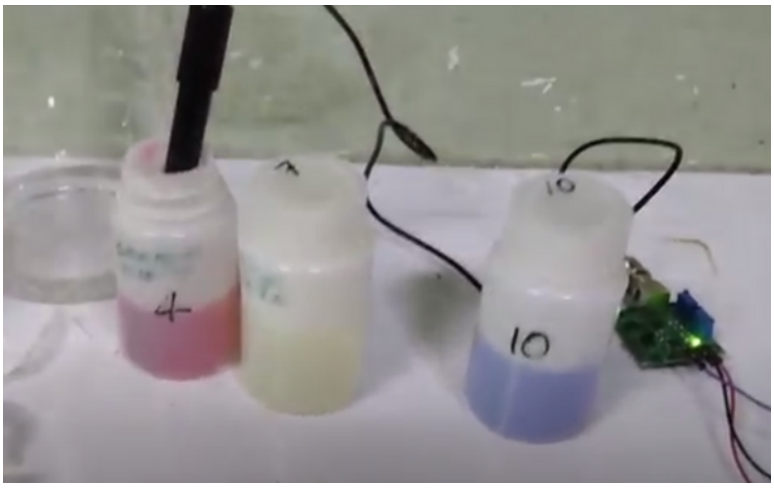


Figure 4.7 Sensor Placed in 4 pH Buffer Solution

Figure 4.8 Sensor Placed in 7 pH Buffer Solution

Figure 4.9 Sensor Placed in 10 pH Buffer Solution

The system was tested by measuring the pH of buffer solutions (4, 7, and 10) within two minutes and recording the pH reading every second, although there is a two seconds delay in measuring the pH from the pH sensor. Figures 4.10, 4.11, and 4.12 show the graph of pH readings measured by the pH monitoring device in buffer solutions with 4, 7, and 10 pH.

During testing of the pH monitoring device, the pH sensor was dipped into a four pH buffer solution, and the sensor's readings ranged from 3.39 to 4.24 pH (see Figure 4.10), which is a good result as the actual readings are significantly close to the pH value 4.

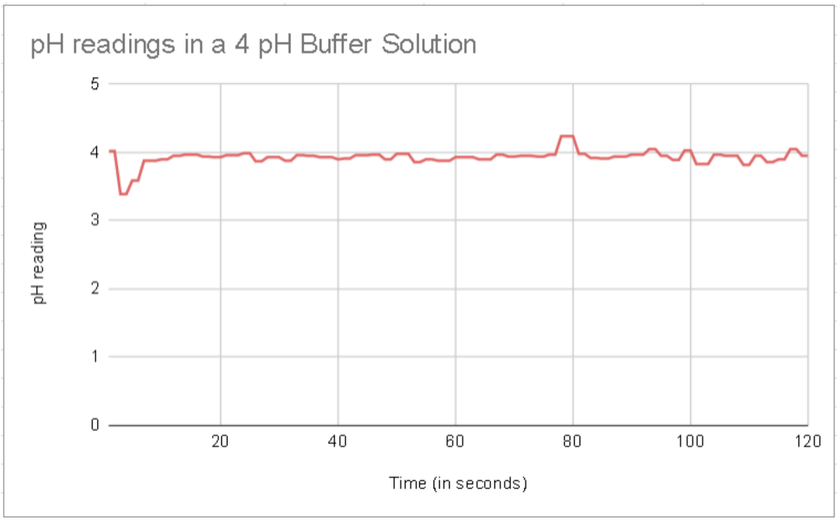


Figure 4.10 pH readings in a 4 pH Buffer Solution

Similarly, the pH sensor was dipped into a 7 pH buffer solution within 2 minutes, and the sensor's readings ranges from 6.937 to 7.227 pH (see Figure 4.11) which is a good result as readings are significantly close to pH value 7.

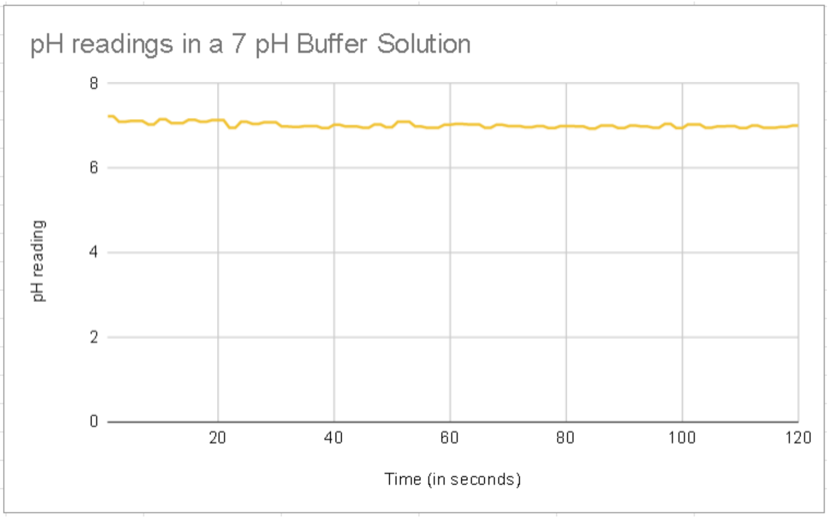


Figure 4.11 pH readings in a 7 pH Buffer Solution

The sensor was also tested in a 10 pH buffer solution, the result is very good as the values are so close to each other and does not fluctuate that much through the whole testing process. The pH values range from 9.951 to 9.981 which also gives high accuracy as it is very close to 10 (see Figure 4.12).

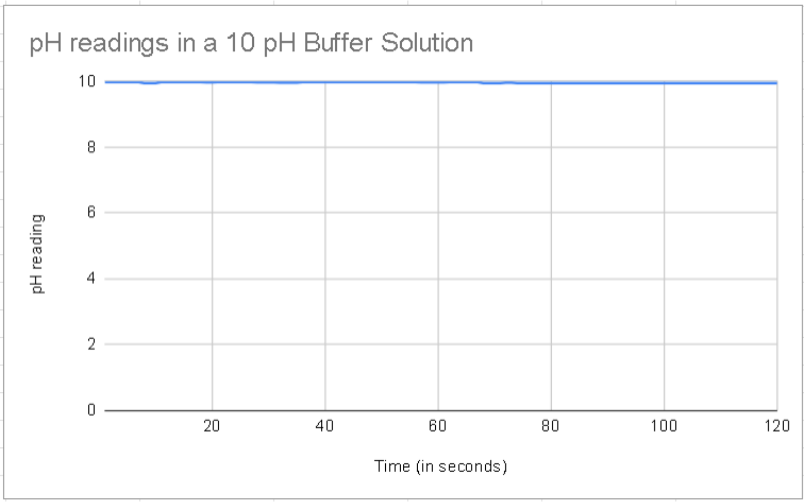


Figure 4.12 pH readings in a 10 pH Buffer Solution

4.1.2 Calculating the Error

The error from the sensor readings is calculated using the Mean Absolute Deviation (MAD), Mean Square Error (MSE), Root Mean Squared Error (RMSE), and Mean Absolute Percentage Error (MAPE). Descriptive statistics of the results are shown in Table 4.1. The total samples of sensor readings are 120 each when testing the pH sensor in three buffer solutions with 4, 7 and 10 pH. The MAD values are 0.089, 0.048, and 0.034 for reading the pH values of three buffer solutions respectively; this indicates better sensor performance because the sensor readings are closer, on average, to the known pH values. Meanwhile, the MSE values are 0.017, 0.0043, and 0.0014. Since the MSE values are lower it means that the actual readings are closer to the known pH values, hence the sensor performs well. This is the same for the other regression metrics such as the RMSE, and the MAPE. The lower their values the closer the sensor readings to the actual pH value of the buffer solution which indicates good performance for the pH sensor.

Table 4.1 Descriptive statistics

Descriptives	4 pH	7 pH	10 pH
n	120	120	120
Lowest Value	3.39	6.947	9.951
Highest Value	4.24	7.227	9.981
MAD	0.089	0.048	0.034
MSE	0.017	0.0043	0.0014
RMSE	0.13	0.069	0.037
MAPE	2.23	0.69	0.34

The error value is also determined using the formula: $Error = (measured\,pH - known\,pH) / known\,pH * 100$. The error value is calculated for each reading every second. Error graphs are generated for the three buffer solutions (see Figures 4.13 to 4.15). These error values are insignificant as they are only small values which means that the measured pH reading is very close to the known pH.

Figure 4.13 shows the error graph of sensor readings in a 4-pH buffer solution. At first few seconds of sensor reading, the calculated error falls to around -17.99, however as the sensor continues to measure the pH value of the solution, the error is lessened, nearing the point of zero. Moreover, it can be seen that most of the calculated errors are negative, which means that the sensor reading is lower than the actual or expected value which is 4-pH. However the calculated errors are not that high which shows that the measured pH is closer than the known pH.

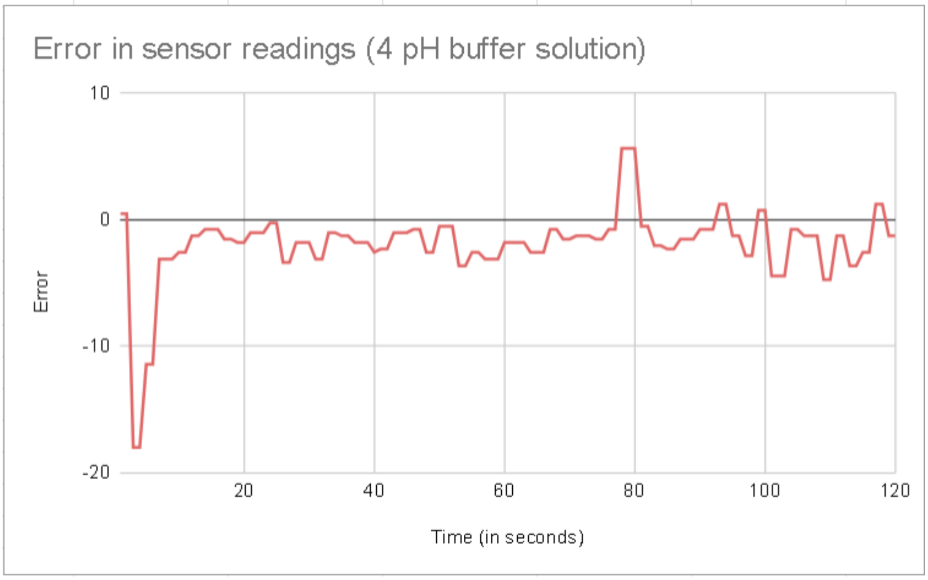


Figure 4.13 Error graph for pH readings in a 4 pH buffer solution

Figure 4.14 shows the calculated error graph of the sensor readings in a 7-pH buffer solution. Compared to the graph above, the calculated error is much less when the sensor measures the pH value in a 7-pH buffer solution. Same with the previous reading, the computed error is higher in the first few seconds of sensor reading; in this case, it reaches 3.24. However, when the sensor continues to read the pH of the 7-pH solution, the error reduces and stays near zero which means that the sensor reading is stabilized near the known pH value of the buffer solution.

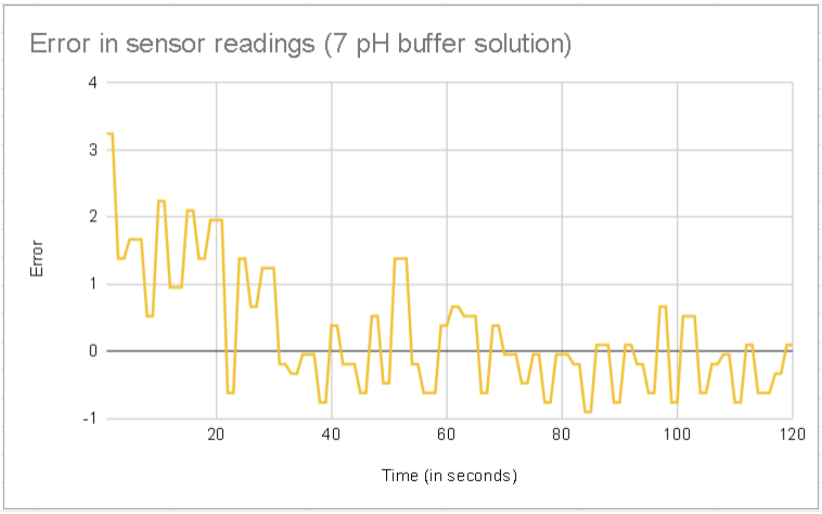


Figure 4.14 Error graph for pH readings in a 7 pH buffer solution

Similarly, Figure 4.15 shows the calculated error graph for sensor reading in a 10-pH buffer solution. The result is impressive as the computed error is very small compared to the previous result from the other two buffer solutions. The highest calculated error is -0.49. However, what was observed here is that the calculated error is not approaching zero; the measured pH value does not reach 10-pH, as the measured pH value ranges from 9.51 to 9.981. Moreover, it can be observed that the calculated error is all negative, implying that the measured pH is lower than the known pH value of the solution. Despite not getting the known pH value, the sensor still gives very close readings to the known pH and a low calculated error which is a good indicator that the system is working accurately.

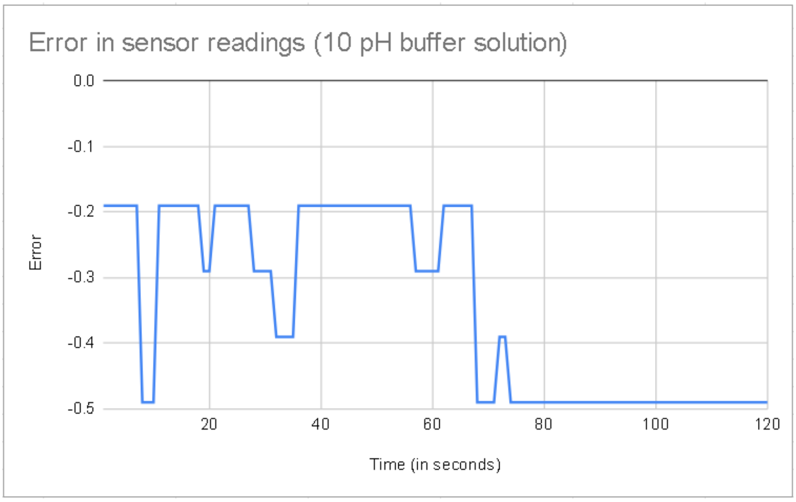


Figure 4.15 Error graph for pH readings in a 10 pH buffer solution

4.2. Agwa Application

4.2.1 Launch Screen

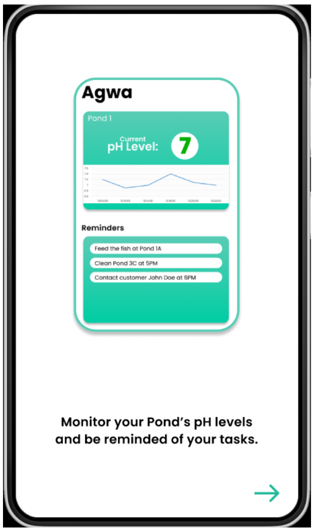
When the user opens the application, they are welcomed by the Agwa logo displayed on the launched screen as shown in Figure 4.16. The screen allows a simple initial experience for the user, providing the application some time to load.

Figure 4.16 Launch Screen (First Page)

Upon clicking the arrow button, a Welcome screen (see Figure 4.17) will be displayed with a simple description of what Agwa's goal is.

Figure 4.17 Greetings Screen (Second Page)

Furthermore, another two pages are displayed after the Greetings Screen. The next pages, as shown in Figures 4.18 and 4.19 will inform the user about the functionalities of the application such as to monitor the pond's pH levels and be reminded of tasks, and get organized by managing the ponds, transactions, and farm activities.



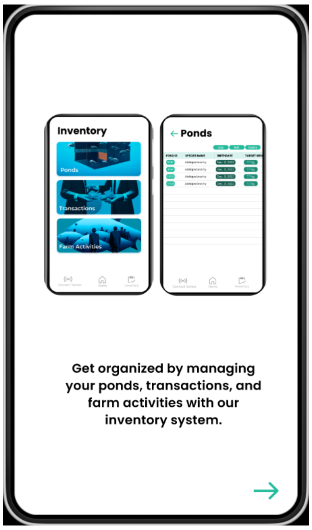
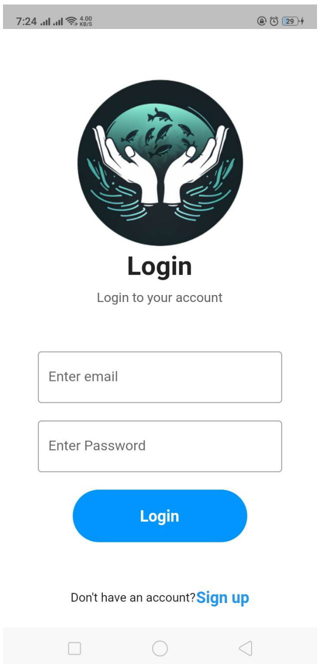


Figure 4.18 Launch Page (Third Page) **Figure 4.19** Launch Screen (Fourth Page)

4.2.2 Log-in/Sign-up

As could be seen in Figures 4.20 and 4.21 the user will then be asked to log-in or sign-up to the application. To sign-up, the user needs to enter an email and password, then the user can log-in to the application by providing the same credentials.



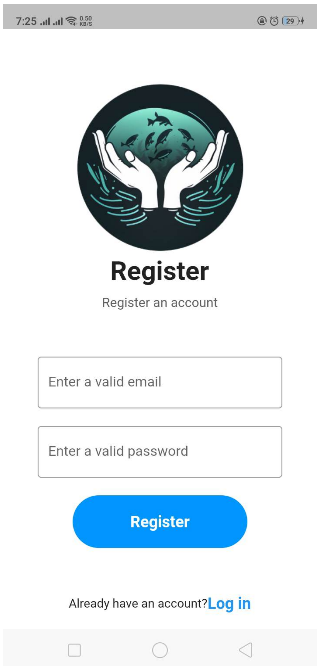


Figure 4.20 Log-in Page **Figure 4.21** Sign-up Page

4.2.3 Home Page

The home page is where the user is redirected after successful login which is shown in Figure 4.22 and 4.23. The pH readings from the sensor will be displayed on the home page. Users can connect to the sensor to view the pH readings in real time (see Figure 4.22) and they can also disconnect to the sensor (Figure 4.23). Moreover, task reminders are also displayed on the home page to remind the user of their upcoming tasks. This would be a user friendly interface as they would immediately see the tasks to be completed as they open the app. If they click the checkbox, a pop up message would appear, asking them if they are sure to mark the task as done (see Figure 4.24).

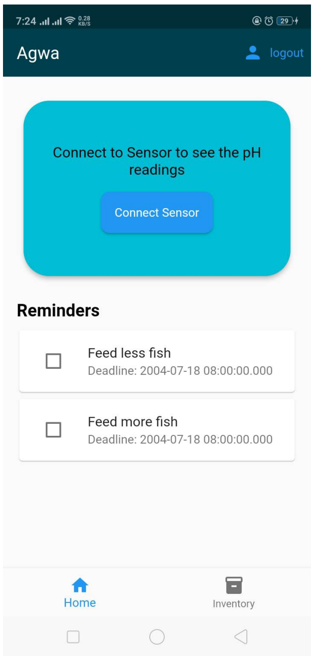


Figure 4.22 Home Page - Connect Sensor

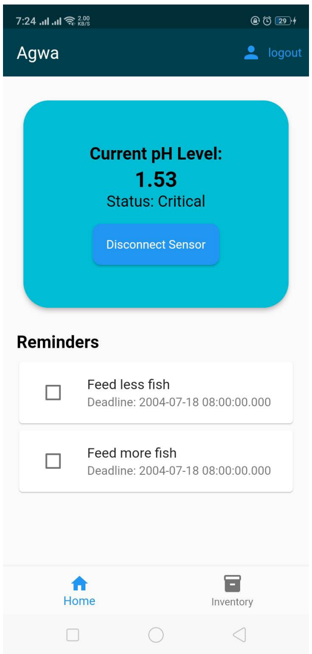


Figure 4.23 Home Page - Disconnect Sensor

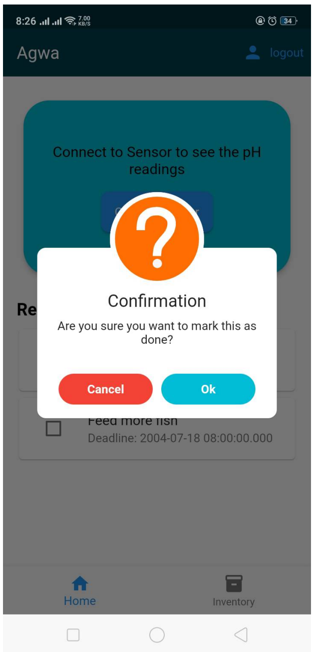


Figure 4.24 Pop-up confirmation

4.2.4 pH Level Alert

Figure 4.25 shows that when the current pH level value goes beyond or below the target pH level range, the mobile application will alert the user that there is something wrong with their water.

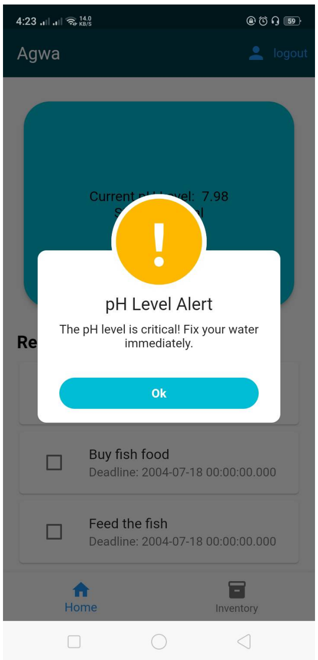


Figure 4.25 pH Level Alert

4.2.5. Inventory Page

Inventory page is where the user can record the information about the ponds, financial transactions within the farm, and keep track of farm activities. As could be seen in Figure 4.26, three different cards are displayed and if clicked will redirect the user to the corresponding inventory.

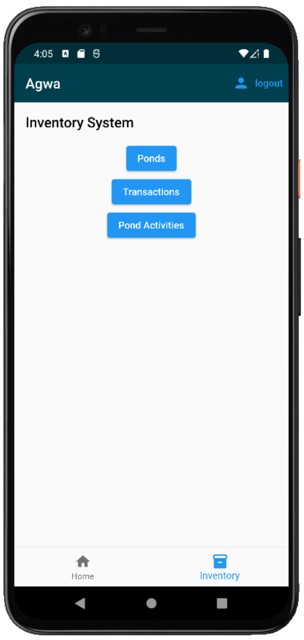


Figure 4.26 Inventory Page

4.2.6 Ponds Inventory

Shown in Figure 4.27 is the ponds inventory page, users can add, edit, and delete ponds data. The “pond” inventory contains the species, species birthdate, species target_weight, target harvest date, species initial quantity, and normal pH level range for healthy growth.

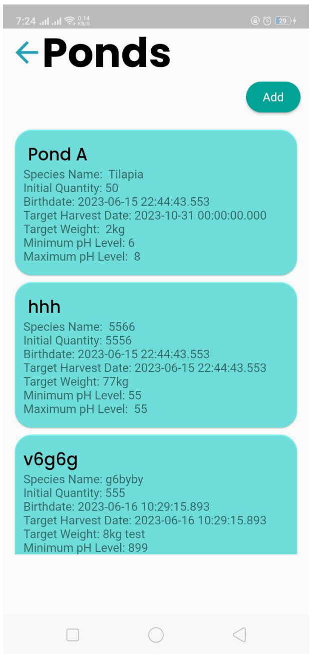


Figure 4.27 Ponds Inventory Page

Transactions Inventory

In the transactions inventory page, users can add, edit, and delete transactions data. As could be seen in Figure 4.28 the transaction inventory contains transaction description, transaction date, amount to identify the amount of revenue or expenses, transaction type if it is an expense or income.

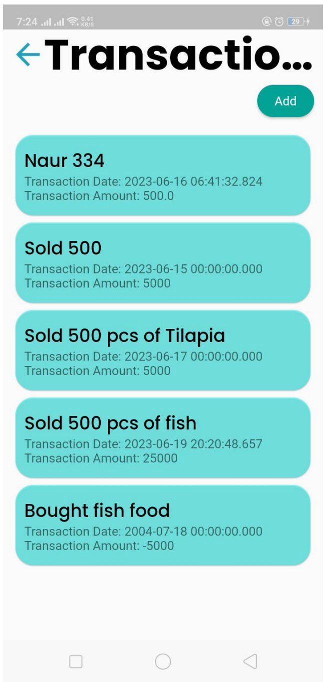


Figure 4.28 Transactions Page

Farm Activities

As what could be seen in Figure 4.29, in the Farm activities inventory page, users can add, edit, and delete farm activities. Furthermore, the farm activities inventory contains task description, deadline, and status which can have a value of done or pending.

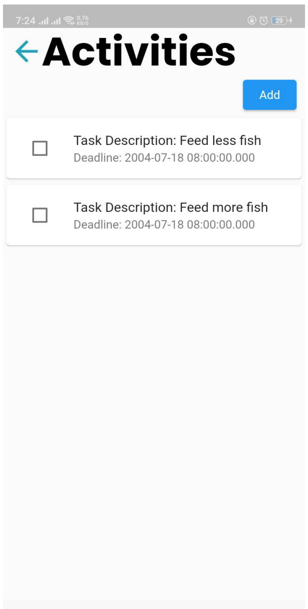


Figure 4.29 Farm Activities

4.3 Hardware Deployment

The system developed in this paper has not yet been deployed in an actual aquaculture environment because of time constraints. However, if this system had more time to be deployed in a simple aquaculture pond, the researchers plan on using the following materials:

4.3.1 Expanded Polystyrene

Expanded polystyrene or EPS, sometimes known as Styrofoam™ Brand Foam, is a lightweight and buoyant material. EPS is an excellent material for floating platforms, especially in maritime and dock applications (Universal Foam Products, 2022). EPS has been utilized in the creation of floating docks that can endure severe ocean conditions and continuous contact with saltwater throughout the year. The flotation blocks made from EPS are resistant to water and can remain functional even if they have been punctured or broken. They are environmentally friendly and convenient to transport and build (Polyform, 2018). The complete hardware system, as shown in Figure 4.1 will be placed on a small EPS platform to keep it afloat on the surface of the pond.

4.3.2 Potting Compounds

If the hardware system is placed in an aquaculture pond, it can be protected by using potting compounds like epoxy resins. These compounds are applied around the microcontroller to create a waterproof barrier and ensure its enclosure is resistant to water. Epoxy resins are a special kind of man-made material that have really good qualities when it comes to electricity and mechanics. They work well for safeguarding electronic parts from things like dust, moisture, and short circuits, additionally, they provide protection against chemicals and high temperatures as well (Cadence PCB Solutions, 2023).

4.3.3 Waterproof Enclosures

The hardware system shown in Figure 4.1 will be placed within a waterproof enclosure made of materials such as Polycarbonate. This type of plastic is useful for watertight enclosures due to its durability and lightweight nature. It offers dependable protection by resisting impacts, UV radiation, and being stable in a variety of temperatures (Polycase, 2023).

The purpose of these enclosures is to keep water out while also protecting the inside components. It is critical to create a tight seal and select a waterproof enclosure based on the desired water depth and period of exposure (Kauffmann, 2014).

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1. Conclusions

Water quality plays a vital role in fish survival and successful growth in aquaculture. The pH level is a significant factor that directly impacts the health of fish. However, numerous aquaculturists fail to manage the pH of the water and also lack essential knowledge regarding their farm's environmental conditions. This oversight can have detrimental consequences, including fish diseases, stunted growth, and even death.

The study implemented an Arduino-based pH water monitoring system and inventory application called Agwa. With Agwa, the user is provided with a device and mobile application that can aid in solving the issues mentioned above. Through the Agwa pH monitoring device, the pH can be monitored onsite by displaying the pH readings on an LCD and a pH description if it is Normal, Acidic, or Basic in real-time. Moreover, with the Agwa mobile application, users won't have to worry about monitoring the water quality in their ponds. As long as there is an internet connection, they can be updated with the water quality wherever they are. Moreover, the application provides an inventory of the pond, transactions, and activities that could help them optimize their record-keeping and farm activities.

5.2. Recommendations

This study presents a solution to the water quality problem in aquaculture and farm record-keeping. Agwa is an application that allows users to monitor water quality by determining the pH even when they are away from the pond. The application also enables the users to keep a record of their farm data and keep track of their activities. With that in mind, Agwa is still in its early stages and is subject to further improvement.

The developers recommend improvements in the technical aspects of the hardware system. The device should be able to connect to any WiFi without re-uploading the WiFi credentials to the hardware if the WiFi is to be changed. Other sensors can be added to the device, such as those that measure dissolved oxygen, temperature, ammonia, etc. Moreover, Bluetooth connection can be integrated with the hardware system so the user can connect to the device even if there is no internet connection.

Meanwhile, the user interface can be further improved for the application by providing graphs of the pH readings. There should also be a history of the past sensor readings on each pond whenever the user wants to review the pH in the past days, months, or years. For the transaction, it would be best if there would be an overview of the total expenses and income of the user periodically to know if they are profiting in the business. Other features can also be added, such as an educational page wherein the user can learn how to maintain a suitable pH and adequately care for their aquatic species.

LITERATURE CITED

Abdul Aleem, R. (2013). Sales and inventory management system. University Technology of PETRONAS. http://utpedia.utp.edu.my/13591/1/Rahmet%20Bee_13743.pdf

Agarwal, T. (2021, October 3). *ESP8266 Wi-Fi Module Datasheet : Working and Its Applications*. ElProCus. Retrieved December 9, 2022, from https://www.elprocus.com/esp8266- wi-fi-module/

Amazon. (2022). *What is Web Hosting? - Web Hosting Explained - AWS*. Amazon Web Services, Inc. https://aws.amazon.com/what-is/web-hosting/

Anita, B., and Pooja, D. (2013). *Water Quality Guidelines for the Management of Pond Fish Culture*, *3*(6), 1980–2009. https://doi.org/10.6088/ijes.2013030600019

aquaManager. (2022). *aquaManager Software*. https://www.aqua-manager.com/software/

Arduino. (2022, December 7). *What is Arduino?: Arduino documentation*. Arduino. Retrieved December 9, 2022, from https://docs.arduino.cc/learn/starting-guide/whats-arduino

Arduino (2023). *Arduino Integrated Development Environment (IDE) v1 | Arduino Documentation*. https://docs.arduino.cc/software/ide-v1/tutorials/arduino-ide-v1-basics

Aride, P. H. R., Roubach, R., and Val, A. L. (2004). Water pH in Central Amazon and its importance for Tambaqui (Colossoma macropomum) culture. *World Aquaculture*, *35*(2), 24–28. https://doi.org/https://www.researchgate.net/profile/Adalberto-Val/publication/312991489_Water_pH_in_central_Amazon_and_its_importance_for_tambaqui_Colossoma_macropomum_culture/links/59922459a6fdcc53b79b6558/Water-pH-in-central-Amazon-and-its-importance-for-tambaqui-Colossoma-macropomum-culture.pdf

Baker, K. (2022, August 8). *The Ultimate Guide to Web Hosting*. https://blog.hubspot.com/website/web-hosting

BFAR. (2021). Philippine fisheries profile 2020. In *Bureau of Fisheries and Aquatic Resources* (ISSN: 2704-3355). Retrieved October 7, 2022, from https://www.bfar.da.gov.ph/wp-content/uploads/2022/02/2020-Fisheries-Profile-Final.pdf

Cadence PCB Solutions. (2023). *Common Methods for Waterproofing Electronics Materials*. Cadence. Retrieved June 19, 2023, from https://resources.pcb.cadence.com/blog/2020-common-methods-for-waterproofing-electronics-materials

Cao, G., Mu, B., Xiao, X., Zhang, L., and Zou, Y. (2021). *Flexible wireless pH sensor system for fish monitoring*. Beijing Laboratory of Food Quality and Safety, College of Engineering, China Agricultural University. https://www.sciencedirect.com/science/article/pii/S2214180421000702

Casanoves, F., de Sousa, K., Detlefsen, G., Rivera, O., de Melo, E., Tobar, D., Castaño-Quintero, M., Aristizabal-Correa, S., Amores-Contreras, F., and de Sousa, C. (2013). Using a smartphone app to support participatory agroforestry planning in Central America. https://foris.fao.org/wfc2015/api/file/55e811918f1f0f9240d2ef73/contents/27de2310-e187-4653-9a08-f7c2d033c3e1.pdf

Cockburn, A. (2006). *Agile software development: the cooperative game*. Pearson Education. https://books.google.com.ph/books?hl=en&lr=&id=i39yimbrzh4C&oi=fnd&pg=PT15&dq=agile+methodology+book&ots=Y8YVe1X66Z&sig=z8v1rXqOTCy52yYA2LSlDHUFsjM&redir_esc=y#v=onepage&q=agile&f=false

DFRobot. (n.d.). Ph meter(sku: Sen0161). Retrieved November 6, 2022, from https://media.digikey.com/pdf/data%20sheets/dfrobot%20pdfs/sen0161_sen0169_web.pdf

DFRobot. (n.d.). *Ph meter(sku: Sen0161)*. Retrieved November 6, 2022, from https://media.digikey.com/pdf/data%20sheets/dfrobot%20pdfs/sen0161_sen0169_web.pdf

Dipay, E. J. (2021). Automatic Water Monitoring System for Tilapia culture with mobile application. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(3), 5351–5356. https://doi.org/10.17762/turcomat.v12i3.2179

DOST. (2021, April 13). Smart aquaculture in MIMAROPA rises: Fostering food security through S&T solutions. Department of Science and Technology. Retrieved October 11, 2022, from https://www.dost.gov.ph/knowledge-resources/news/72-2021-news/2185-smart-aquaculture-in-mimaropa-rises-fostering-food-security-through-s-t-solutions.html

FAO. (2022). *National Aquaculture Sector Overview (Philippines)*. Food and Agriculture Organization of the United Nations. Retrieved October 7, 2022, from https://www.fao.org/fishery/en/countrysector/naso_philippines

Firebase. (2022). *Make your app the best it can be*. Firebase.google. https://firebase.google.com/

Firebase. (n.d.). *Firebase*. https://firebase.google.com/

Flutter. (n.d.). *Build apps for any screen*. Flutter. Retrieved December 12, 2022, from https://flutter.dev/

Geppert, A., and Dittrich, K. (2001). *Component Database Systems*. https://doi.org/10.1016/B978-155860642-5/50002-X

GOIS. (2020, June 22). *The growing importance of inventory management for agriculture firms.* Blog. Retrieved October 11, 2022, from https://blog.goodsorderinventory.com/agricultural/the-growing-importance-of-inventory-management-for-agriculture-firms/

Google Developers (2022, December 6). *Meet android studio : Android developers*. (2022, December 6). Google Developers. Retrieved December 9, 2022, from https://developer.android.com/studio/intro

Harun, Z., Reda, E., and Hashim, H. (2018). Real time fish pond monitoring and automation using Arduino. *IOP Conference Series: Materials Science and Engineering*, *340*. https://doi.org/10.1088/1757-899x/340/1/012014

IBM. (2010). *Database management systems on z/OS*. © Copyright IBM Corporation 2010.

https://www.ibm.com/docs/en/zos-basic-skills?topic=zos-what-is-database-management-system

Kauffmann, T. (2014). Making a Waterproof Case for Solar Powered Microcontrollers. *Voltaic Systems*. https://blog.voltaicsystems.com/making-a-weatherproof-case-for-solar-powered-microcontrollers/

Kinsta. (2022, December 6). *What is github? A beginner's introduction to github*. Kinsta. Retrieved November 30, 2022, from https://kinsta.com/knowledgebase/what-is-github/

Labs Nova. (2021, December 10). *What is ph meter?* Labrotovap. Retrieved November 6, 2022, from https://www.labrotovap.com/what-is-ph-meter/

Makerlab Electronics. (n.d.). *NodeMCU V3 ESP8266 ESP-12E Philippines Makerlab Electronics*. https://makerlab-electronics.com/products/nodemcu-v3-esp8266-esp-12e

Merriam-Webster. (2022, December 6). *Smartphone definition and meaning*. Merriam-Webster. Retrieved November 30, 2022, from https://www.merriam-webster.com/dictionary/smartphone

Mustapha, A. (2019). *Importance of PH Control in Aquaculture*. https://doi.org/https://www.researchgate.net/publication/340870601_IMPORTANCE_OF_pH_CONTROL_IN_AQUACULTURE

Nasution, T. H., Dika, S., Sinulingga, E. P., Tanjung, K., and Harahap, L. A. (2020). Analysis of the use of SEN0161 ph sensor for water in Goldfish Ponds. *IOP*

Conference Series: Materials Science and Engineering, *851*(1), 012053. https://doi.org/10.1088/1757-899x/851/1/012053

NOAA. (2021, February 26). *What is aquaculture?* National Oceanic and Atmospheric Administration. Retrieved October 7, 2022, from https://oceanservice.noaa.gov/facts/aquaculture.html

Oracle. (2022). *What is a Relational Database (RDBMS)?* OCI. https://www.oracle.com/ph/database/what-is-a-relational-database/

P.A., A., Enyindah, C., and Etuk, M. (2021). *The role of Technology on Aquaculture*. Retrieved October 11, 2022, from https://www.academia.edu/50136217/The_role_of_Technology_on_Aquaculture

Pandora FMS team. (2022, November 8). *Why do you need a monitoring system? - all you need to know*. Pandora FMS Monitoring Blog. Retrieved November 17, 2022, from https://pandorafms.com/blog/why-you-need-a-monitoring-system/

Perera, R. (2020, September 17). *What is Figma? (and how to use Figma for beginners)*. Theme Junkie. Retrieved November 30, 2022, from https://www.theme-junkie.com/what-is-figma/

Polycase. (2023). *Waterproof Enclosures and Boxes*. Retrieved June 19, 2023, from https://www.polycase.com/waterproof-enclosures

Polyform. (2018, April 26). Expanded Polystyrene and the Art of Flotation. Retrieved June 19, 2023, from https://www.polyform.com/newsletter/expanded-polystyrene-and-the-art-of-flotation-156/?lang=en

Pramana, R., Suprapto, B. Y., and Nawawi, Z. (2021). Remote water quality monitoring with early –warning system for marine aquaculture. *E3S Web of Conferences*, *324*, 05007. https://doi.org/10.1051/e3sconf/202132405007

SEAFDEC. (2022, August 17). *Farmers must understand the costs of tech-driven aquaculture - SEAFDEC/AQD*. SEAFDEC/AQD - Southeast Asian Fisheries Development Center | Aquaculture Department. Retrieved October 7, 2022, from https://www.seafdec.org.ph/2022/farmers-must-understand-the-costs-of-tech-driven-aquaculture/

Singh, D., and Verma, A. (2018). Inventory management in supply chain. Materials Today: Proceedings, 5(2), 3867-3872. https://bit.ly/3g8Q1JZ

Single Spark The Netherlands. (2020). ရွှေငါး - Shwe Ngar (Version 1.8.3) [Mobile app]. Google Play Store. https://play.google.com/store/apps/details?id=nl.singlespark.goldenfish&hl=be&pli=1

Solomon, K. (2022, May 25). *What is Trello used for? project management software explained: Trello*. A blog for teams by Trello. Retrieved Nov 30, 2022, from https://blog.trello.com/what-is-trello-used-for

Sommerville, I. (2011). *Software Engineering* (9th ed.). Pearson Education. https://edisciplinas.usp.br/pluginfile.php/2150022/mod_resource/content/1/1429431793.203Software%20Engineering%20by%20Somerville.pdf

Techopedia. (2017, June 27). *What is a laptop? - definition from Techopedia*. Techopedia. Retrieved November 30, 2022, from https://www.techopedia.com/definition/5300/laptop

Universal Foam Products. (2022). *Marine And Dock Flotation*. Retrieved June 19, 2023, from https://univfoam.com/products/flotation

Wang, Y. (2022). Design and implementation of online water quality monitoring system. *Highlights in Science, Engineering and Technology*, *7*, 288–293. https://doi.org/10.54097/hset.v7i.1084

Yokogawa Philippines Inc. (n.d.). *Ph in fish farming*. Retrieved September 26, 2022, from https://www.yokogawa.com/ph/library/resources/application-notes/ph-in-fish-farming/

Zepernick, B. N., Gann, E. R., Martin, R. M., Pound, H. L., Krausfeldt, L. E., Chaffin, J. D., and Wilhelm, S. W. (2021). Elevated ph conditions associated with Microcystis spp.. blooms decrease viability of the cultured diatom fragilaria crotonensis and natural diatoms in Lake Erie. *Frontiers in Microbiology*, *12*. https://doi.org/10.3389/fmicb.2021.598736

APPENDICES

Appendix A: Timetable of Activities

Activities	Sept	Oct	Nov	Dec	Jan	Feb	Ma r	Apr	May	Jun
Present a Topic Proposal	***									
Identify the features of the system	***									
Research on related studies and literature		***								
List the product backlogs			***							
Design the system				***						
Create the prototype of the system				***	***					
Perform Sprints in developing the system				***	***	***	***	***	***	***

Appendix B. Test Results

Buffer Solution: 7 pH						
Time (in seconds)	pH reading	Known pH	Error	Absolute Value of Error	Square of Error	Absolute Value of Errors Divided by Actual Values
1	7.227	7	-0.227	0.227	0.051529	0.03242857143
2	7.227	7	-0.227	0.227	0.051529	0.03242857143
3	7.097	7	-0.097	0.097	0.009409	0.01385714286
4	7.097	7	-0.097	0.097	0.009409	0.01385714286
5	7.117	7	-0.117	0.117	0.013689	0.01671428571
6	7.117	7	-0.117	0.117	0.013689	0.01671428571
7	7.117	7	-0.117	0.117	0.013689	0.01671428571
8	7.037	7	-0.037	0.037	0.001369	0.005285714286
9	7.037	7	-0.037	0.037	0.001369	0.005285714286
10	7.157	7	-0.157	0.157	0.024649	0.02242857143
11	7.157	7	-0.157	0.157	0.024649	0.02242857143
12	7.067	7	-0.067	0.067	0.004489	0.009571428571
13	7.067	7	-0.067	0.067	0.004489	0.009571428571
14	7.067	7	-0.067	0.067	0.004489	0.009571428571
15	7.147	7	-0.147	0.147	0.021609	0.021
16	7.147	7	-0.147	0.147	0.021609	0.021
17	7.097	7	-0.097	0.097	0.009409	0.01385714286
18	7.097	7	-0.097	0.097	0.009409	0.01385714286
19	7.137	7	-0.137	0.137	0.018769	0.01957142857
20	7.137	7	-0.137	0.137	0.018769	0.01957142857
21	7.137	7	-0.137	0.137	0.018769	0.01957142857
22	6.957	7	0.043	0.043	0.001849	0.006142857143
23	6.957	7	0.043	0.043	0.001849	0.006142857143
24	7.097	7	-0.097	0.097	0.009409	0.01385714286
25	7.097	7	-0.097	0.097	0.009409	0.01385714286
26	7.047	7	-0.047	0.047	0.002209	0.006714285714
27	7.047	7	-0.047	0.047	0.002209	0.006714285714
28	7.087	7	-0.087	0.087	0.007569	0.01242857143
29	7.087	7	-0.087	0.087	0.007569	0.01242857143
30	7.087	7	-0.087	0.087	0.007569	0.01242857143
31	6.987	7	0.013	0.013	0.000169	0.001857142857
32	6.987	7	0.013	0.013	0.000169	0.001857142857
33	6.977	7	0.023	0.023	0.000529	0.003285714286
34	6.977	7	0.023	0.023	0.000529	0.003285714286
35	6.997	7	0.003	0.003	0.000009	0.000428571428
36	6.997	7	0.003	0.003	0.000009	0.000428571428
37	6.997	7	0.003	0.003	0.000009	0.000428571428
38	6.947	7	0.053	0.053	0.002809	0.007571428571
39	6.947	7	0.053	0.053	0.002809	0.007571428571
40	7.027	7	-0.027	0.027	0.000729	0.003857142857
41	7.027	7	-0.027	0.027	0.000729	0.003857142857
42	6.987	7	0.013	0.013	0.000169	0.001857142857

43	6.987	7	0.013	0.013	0.000169	0.001857142857
44	6.987	7	0.013	0.013	0.000169	0.001857142857
45	6.957	7	0.043	0.043	0.001849	0.006142857143
46	6.957	7	0.043	0.043	0.001849	0.006142857143
47	7.037	7	-0.037	0.037	0.001369	0.005285714286
48	7.037	7	-0.037	0.037	0.001369	0.005285714286
49	6.967	7	0.033	0.033	0.001089	0.004714285714
50	6.967	7	0.033	0.033	0.001089	0.004714285714
51	7.097	7	-0.097	0.097	0.009409	0.01385714286
52	7.097	7	-0.097	0.097	0.009409	0.01385714286
53	7.097	7	-0.097	0.097	0.009409	0.01385714286
54	6.987	7	0.013	0.013	0.000169	0.001857142857
55	6.987	7	0.013	0.013	0.000169	0.001857142857
56	6.957	7	0.043	0.043	0.001849	0.006142857143
57	6.957	7	0.043	0.043	0.001849	0.006142857143
58	6.957	7	0.043	0.043	0.001849	0.006142857143
59	7.027	7	-0.027	0.027	0.000729	0.003857142857
60	7.027	7	-0.027	0.027	0.000729	0.003857142857
61	7.047	7	-0.047	0.047	0.002209	0.006714285714
62	7.047	7	-0.047	0.047	0.002209	0.006714285714
63	7.037	7	-0.037	0.037	0.001369	0.005285714286
64	7.037	7	-0.037	0.037	0.001369	0.005285714286
65	7.037	7	-0.037	0.037	0.001369	0.005285714286
66	6.957	7	0.043	0.043	0.001849	0.006142857143
67	6.957	7	0.043	0.043	0.001849	0.006142857143
68	7.027	7	-0.027	0.027	0.000729	0.003857142857
69	7.027	7	-0.027	0.027	0.000729	0.003857142857
70	6.997	7	0.003	0.003	0.000009	0.000428571428
71	6.997	7	0.003	0.003	0.000009	0.000428571428
72	6.997	7	0.003	0.003	0.000009	0.000428571428
73	6.967	7	0.033	0.033	0.001089	0.004714285714
74	6.967	7	0.033	0.033	0.001089	0.004714285714
75	6.997	7	0.003	0.003	0.000009	0.000428571428
76	6.997	7	0.003	0.003	0.000009	0.000428571428
77	6.947	7	0.053	0.053	0.002809	0.007571428571
78	6.947	7	0.053	0.053	0.002809	0.007571428571
79	6.997	7	0.003	0.003	0.000009	0.000428571428
80	6.997	7	0.003	0.003	0.000009	0.000428571428
81	6.997	7	0.003	0.003	0.000009	0.000428571428
82	6.987	7	0.013	0.013	0.000169	0.001857142857
83	6.987	7	0.013	0.013	0.000169	0.001857142857
84	6.937	7	0.063	0.063	0.003969	0.009

85	6.937	7	0.063	0.063	0.003969	0.009
86	7.007	7	-0.007	0.007	0.000049	0.001
87	7.007	7	-0.007	0.007	0.000049	0.001
88	7.007	7	-0.007	0.007	0.000049	0.001
89	6.947	7	0.053	0.053	0.002809	0.007571428571
90	6.947	7	0.053	0.053	0.002809	0.007571428571
91	7.007	7	-0.007	0.007	0.000049	0.001
92	7.007	7	-0.007	0.007	0.000049	0.001
93	6.987	7	0.013	0.013	0.000169	0.001857142857
94	6.987	7	0.013	0.013	0.000169	0.001857142857
95	6.957	7	0.043	0.043	0.001849	0.006142857143
96	6.957	7	0.043	0.043	0.001849	0.006142857143
97	7.047	7	-0.047	0.047	0.002209	0.006714285714
98	7.047	7	-0.047	0.047	0.002209	0.006714285714
99	6.947	7	0.053	0.053	0.002809	0.007571428571
100	6.947	7	0.053	0.053	0.002809	0.007571428571
101	7.037	7	-0.037	0.037	0.001369	0.005285714286
102	7.037	7	-0.037	0.037	0.001369	0.005285714286
103	7.037	7	-0.037	0.037	0.001369	0.005285714286
104	6.957	7	0.043	0.043	0.001849	0.006142857143
105	6.957	7	0.043	0.043	0.001849	0.006142857143
106	6.987	7	0.013	0.013	0.000169	0.001857142857
107	6.987	7	0.013	0.013	0.000169	0.001857142857
108	6.997	7	0.003	0.003	0.000009	0.00042857142
109	6.997	7	0.003	0.003	0.000009	0.00042857142
110	6.947	7	0.053	0.053	0.002809	0.007571428571
111	6.947	7	0.053	0.053	0.002809	0.007571428571
112	7.007	7	-0.007	0.007	0.000049	0.001
113	7.007	7	-0.007	0.007	0.000049	0.001
114	6.957	7	0.043	0.043	0.001849	0.006142857143
115	6.957	7	0.043	0.043	0.001849	0.006142857143
116	6.957	7	0.043	0.043	0.001849	0.006142857143
117	6.977	7	0.023	0.023	0.000529	0.003285714286
118	6.977	7	0.023	0.023	0.000529	0.003285714286
119	7.007	7	-0.007	0.007	0.000049	0.001
120	7.007	7	-0.007	0.007	0.000049	0.001
		Totals	-2.26	5.812	0.51996	0.8302857143

Buffer Solution: 4 pH						
Time (in seconds)	pH reading	Known pH	Error	Absolute Value of Error	Square of Error	Absolute Value of Errors Divided by Actual Values
1	4.02	4	-0.02	0.02	0.0004	0.005
2	4.02	4	-0.02	0.02	0.0004	0.005
3	3.39	4	0.61	0.61	0.3721	0.1525
4	3.39	4	0.61	0.61	0.3721	0.1525
5	3.59	4	0.41	0.41	0.1681	0.1025
6	3.59	4	0.41	0.41	0.1681	0.1025
7	3.88	4	0.12	0.12	0.0144	0.03
8	3.88	4	0.12	0.12	0.0144	0.03
9	3.88	4	0.12	0.12	0.0144	0.03
10	3.9	4	0.1	0.1	0.01	0.025
11	3.9	4	0.1	0.1	0.01	0.025
12	3.95	4	0.05	0.05	0.0025	0.0125
13	3.95	4	0.05	0.05	0.0025	0.0125
14	3.97	4	0.03	0.03	0.0009	0.0075
15	3.97	4	0.03	0.03	0.0009	0.0075
16	3.97	4	0.03	0.03	0.0009	0.0075
17	3.94	4	0.06	0.06	0.0036	0.015
18	3.94	4	0.06	0.06	0.0036	0.015
19	3.93	4	0.07	0.07	0.0049	0.0175
20	3.93	4	0.07	0.07	0.0049	0.0175
21	3.96	4	0.04	0.04	0.0016	0.01
22	3.96	4	0.04	0.04	0.0016	0.01
23	3.96	4	0.04	0.04	0.0016	0.01
24	3.99	4	0.01	0.01	0.0001	0.0025
25	3.99	4	0.01	0.01	0.0001	0.0025
26	3.87	4	0.13	0.13	0.0169	0.0325
27	3.87	4	0.13	0.13	0.0169	0.0325
28	3.93	4	0.07	0.07	0.0049	0.0175
29	3.93	4	0.07	0.07	0.0049	0.0175
30	3.93	4	0.07	0.07	0.0049	0.0175
31	3.88	4	0.12	0.12	0.0144	0.03
32	3.88	4	0.12	0.12	0.0144	0.03
33	3.96	4	0.04	0.04	0.0016	0.01
34	3.96	4	0.04	0.04	0.0016	0.01
35	3.95	4	0.05	0.05	0.0025	0.0125
36	3.95	4	0.05	0.05	0.0025	0.0125
37	3.93	4	0.07	0.07	0.0049	0.0175
38	3.93	4	0.07	0.07	0.0049	0.0175
39	3.93	4	0.07	0.07	0.0049	0.0175
40	3.9	4	0.1	0.1	0.01	0.025
41	3.91	4	0.09	0.09	0.0081	0.0225
42	3.91	4	0.09	0.09	0.0081	0.0225

43	3.96	4	0.04	0.04	0.0016	0.01
44	3.96	4	0.04	0.04	0.0016	0.01
45	3.96	4	0.04	0.04	0.0016	0.01
46	3.97	4	0.03	0.03	0.0009	0.0075
47	3.97	4	0.03	0.03	0.0009	0.0075
48	3.9	4	0.1	0.1	0.01	0.025
49	3.9	4	0.1	0.1	0.01	0.025
50	3.98	4	0.02	0.02	0.0004	0.005
51	3.98	4	0.02	0.02	0.0004	0.005
52	3.98	4	0.02	0.02	0.0004	0.005
53	3.86	4	0.14	0.14	0.0196	0.035
54	3.86	4	0.14	0.14	0.0196	0.035
55	3.9	4	0.1	0.1	0.01	0.025
56	3.9	4	0.1	0.1	0.01	0.025
57	3.88	4	0.12	0.12	0.0144	0.03
58	3.88	4	0.12	0.12	0.0144	0.03
59	3.88	4	0.12	0.12	0.0144	0.03
60	3.93	4	0.07	0.07	0.0049	0.0175
61	3.93	4	0.07	0.07	0.0049	0.0175
62	3.93	4	0.07	0.07	0.0049	0.0175
63	3.93	4	0.07	0.07	0.0049	0.0175
64	3.9	4	0.1	0.1	0.01	0.025
65	3.9	4	0.1	0.1	0.01	0.025
66	3.9	4	0.1	0.1	0.01	0.025
67	3.97	4	0.03	0.03	0.0009	0.0075
68	3.97	4	0.03	0.03	0.0009	0.0075
69	3.94	4	0.06	0.06	0.0036	0.015
70	3.94	4	0.06	0.06	0.0036	0.015
71	3.95	4	0.05	0.05	0.0025	0.0125
72	3.95	4	0.05	0.05	0.0025	0.0125
73	3.95	4	0.05	0.05	0.0025	0.0125
74	3.94	4	0.06	0.06	0.0036	0.015
75	3.94	4	0.06	0.06	0.0036	0.015
76	3.97	4	0.03	0.03	0.0009	0.0075
77	3.97	4	0.03	0.03	0.0009	0.0075
78	4.24	4	-0.24	0.24	0.0576	0.06
79	4.24	4	-0.24	0.24	0.0576	0.06
80	4.24	4	-0.24	0.24	0.0576	0.06
81	3.98	4	0.02	0.02	0.0004	0.005
82	3.98	4	0.02	0.02	0.0004	0.005
83	3.92	4	0.08	0.08	0.0064	0.02
84	3.92	4	0.08	0.08	0.0064	0.02

85	3.91	4	0.09	0.09	0.0081	0.0225
86	3.91	4	0.09	0.09	0.0081	0.0225
87	3.94	4	0.06	0.06	0.0036	0.015
88	3.94	4	0.06	0.06	0.0036	0.015
89	3.94	4	0.06	0.06	0.0036	0.015
90	3.97	4	0.03	0.03	0.0009	0.0075
91	3.97	4	0.03	0.03	0.0009	0.0075
92	3.97	4	0.03	0.03	0.0009	0.0075
93	4.05	4	-0.05	0.05	0.0025	0.0125
94	4.05	4	-0.05	0.05	0.0025	0.0125
95	3.95	4	0.05	0.05	0.0025	0.0125
96	3.95	4	0.05	0.05	0.0025	0.0125
97	3.89	4	0.11	0.11	0.0121	0.0275
98	3.89	4	0.11	0.11	0.0121	0.0275
99	4.03	4	-0.03	0.03	0.0009	0.0075
100	4.03	4	-0.03	0.03	0.0009	0.0075
101	3.83	4	0.17	0.17	0.0289	0.0425
102	3.83	4	0.17	0.17	0.0289	0.0425
103	3.83	4	0.17	0.17	0.0289	0.0425
104	3.97	4	0.03	0.03	0.0009	0.0075
105	3.97	4	0.03	0.03	0.0009	0.0075
106	3.95	4	0.05	0.05	0.0025	0.0125
107	3.95	4	0.05	0.05	0.0025	0.0125
108	3.95	4	0.05	0.05	0.0025	0.0125
109	3.82	4	0.18	0.18	0.0324	0.045
110	3.82	4	0.18	0.18	0.0324	0.045
111	3.95	4	0.05	0.05	0.0025	0.0125
112	3.95	4	0.05	0.05	0.0025	0.0125
113	3.86	4	0.14	0.14	0.0196	0.035
114	3.86	4	0.14	0.14	0.0196	0.035
115	3.9	4	0.1	0.1	0.01	0.025
116	3.9	4	0.1	0.1	0.01	0.025
117	4.05	4	-0.05	0.05	0.0025	0.0125
118	4.05	4	-0.05	0.05	0.0025	0.0125
119	3.95	4	0.05	0.05	0.0025	0.0125
120	3.95	4	0.05	0.05	0.0025	0.0125
		Totals	8.65	10.69	1.9929	2.6725

Buffer Solution: 10 pH						
Time (in seconds)	pH reading	Known pH	Error	Absolute Value of Error	Square of Error	Absolute Value of Errors Divided by Actual Values
1	9.981	10	0.019	0.019	0.000361	0.0019
2	9.981	10	0.019	0.019	0.000361	0.0019
3	9.981	10	0.019	0.019	0.000361	0.0019
4	9.981	10	0.019	0.019	0.000361	0.0019
5	9.981	10	0.019	0.019	0.000361	0.0019
6	9.981	10	0.019	0.019	0.000361	0.0019
7	9.981	10	0.019	0.019	0.000361	0.0019
8	9.951	10	0.049	0.049	0.002401	0.0049
9	9.951	10	0.049	0.049	0.002401	0.0049
10	9.951	10	0.049	0.049	0.002401	0.0049
11	9.981	10	0.019	0.019	0.000361	0.0019
12	9.981	10	0.019	0.019	0.000361	0.0019
13	9.981	10	0.019	0.019	0.000361	0.0019
14	9.981	10	0.019	0.019	0.000361	0.0019
15	9.981	10	0.019	0.019	0.000361	0.0019
16	9.981	10	0.019	0.019	0.000361	0.0019
17	9.981	10	0.019	0.019	0.000361	0.0019
18	9.981	10	0.019	0.019	0.000361	0.0019
19	9.971	10	0.029	0.029	0.000841	0.0029
20	9.971	10	0.029	0.029	0.000841	0.0029
21	9.981	10	0.019	0.019	0.000361	0.0019
22	9.981	10	0.019	0.019	0.000361	0.0019
23	9.981	10	0.019	0.019	0.000361	0.0019
24	9.981	10	0.019	0.019	0.000361	0.0019
25	9.981	10	0.019	0.019	0.000361	0.0019
26	9.981	10	0.019	0.019	0.000361	0.0019
27	9.981	10	0.019	0.019	0.000361	0.0019
28	9.971	10	0.029	0.029	0.000841	0.0029
29	9.971	10	0.029	0.029	0.000841	0.0029
30	9.971	10	0.029	0.029	0.000841	0.0029
31	9.971	10	0.029	0.029	0.000841	0.0029
32	9.961	10	0.039	0.039	0.001521	0.0039
33	9.961	10	0.039	0.039	0.001521	0.0039
34	9.961	10	0.039	0.039	0.001521	0.0039
35	9.961	10	0.039	0.039	0.001521	0.0039
36	9.981	10	0.019	0.019	0.000361	0.0019
37	9.981	10	0.019	0.019	0.000361	0.0019
38	9.981	10	0.019	0.019	0.000361	0.0019
39	9.981	10	0.019	0.019	0.000361	0.0019
40	9.981	10	0.019	0.019	0.000361	0.0019
41	9.981	10	0.019	0.019	0.000361	0.0019
42	9.981	10	0.019	0.019	0.000361	0.0019

43	9.981	10	0.019	0.019	0.000361	0.0019
44	9.981	10	0.019	0.019	0.000361	0.0019
45	9.981	10	0.019	0.019	0.000361	0.0019
46	9.981	10	0.019	0.019	0.000361	0.0019
47	9.981	10	0.019	0.019	0.000361	0.0019
48	9.981	10	0.019	0.019	0.000361	0.0019
49	9.981	10	0.019	0.019	0.000361	0.0019
50	9.981	10	0.019	0.019	0.000361	0.0019
51	9.981	10	0.019	0.019	0.000361	0.0019
52	9.981	10	0.019	0.019	0.000361	0.0019
53	9.981	10	0.019	0.019	0.000361	0.0019
54	9.981	10	0.019	0.019	0.000361	0.0019
55	9.981	10	0.019	0.019	0.000361	0.0019
56	9.981	10	0.019	0.019	0.000361	0.0019
57	9.971	10	0.029	0.029	0.000841	0.0029
58	9.971	10	0.029	0.029	0.000841	0.0029
59	9.971	10	0.029	0.029	0.000841	0.0029
60	9.971	10	0.029	0.029	0.000841	0.0029
61	9.971	10	0.029	0.029	0.000841	0.0029
62	9.981	10	0.019	0.019	0.000361	0.0019
63	9.981	10	0.019	0.019	0.000361	0.0019
64	9.981	10	0.019	0.019	0.000361	0.0019
65	9.981	10	0.019	0.019	0.000361	0.0019
66	9.981	10	0.019	0.019	0.000361	0.0019
67	9.981	10	0.019	0.019	0.000361	0.0019
68	9.951	10	0.049	0.049	0.002401	0.0049
69	9.951	10	0.049	0.049	0.002401	0.0049
70	9.951	10	0.049	0.049	0.002401	0.0049
71	9.951	10	0.049	0.049	0.002401	0.0049
72	9.961	10	0.039	0.039	0.001521	0.0039
73	9.961	10	0.039	0.039	0.001521	0.0039
74	9.951	10	0.049	0.049	0.002401	0.0049
75	9.951	10	0.049	0.049	0.002401	0.0049
76	9.951	10	0.049	0.049	0.002401	0.0049
77	9.951	10	0.049	0.049	0.002401	0.0049
78	9.951	10	0.049	0.049	0.002401	0.0049
79	9.951	10	0.049	0.049	0.002401	0.0049
80	9.951	10	0.049	0.049	0.002401	0.0049
81	9.951	10	0.049	0.049	0.002401	0.0049
82	9.951	10	0.049	0.049	0.002401	0.0049
83	9.951	10	0.049	0.049	0.002401	0.0049
84	9.951	10	0.049	0.049	0.002401	0.0049

85	9.951	10	0.049	0.049	0.002401	0.0049
86	9.951	10	0.049	0.049	0.002401	0.0049
87	9.951	10	0.049	0.049	0.002401	0.0049
88	9.951	10	0.049	0.049	0.002401	0.0049
89	9.951	10	0.049	0.049	0.002401	0.0049
90	9.951	10	0.049	0.049	0.002401	0.0049
91	9.951	10	0.049	0.049	0.002401	0.0049
92	9.951	10	0.049	0.049	0.002401	0.0049
93	9.951	10	0.049	0.049	0.002401	0.0049
94	9.951	10	0.049	0.049	0.002401	0.0049
95	9.951	10	0.049	0.049	0.002401	0.0049
96	9.951	10	0.049	0.049	0.002401	0.0049
97	9.951	10	0.049	0.049	0.002401	0.0049
98	9.951	10	0.049	0.049	0.002401	0.0049
99	9.951	10	0.049	0.049	0.002401	0.0049
100	9.951	10	0.049	0.049	0.002401	0.0049
101	9.951	10	0.049	0.049	0.002401	0.0049
102	9.951	10	0.049	0.049	0.002401	0.0049
103	9.951	10	0.049	0.049	0.002401	0.0049
104	9.951	10	0.049	0.049	0.002401	0.0049
105	9.951	10	0.049	0.049	0.002401	0.0049
106	9.951	10	0.049	0.049	0.002401	0.0049
107	9.951	10	0.049	0.049	0.002401	0.0049
108	9.951	10	0.049	0.049	0.002401	0.0049
109	9.951	10	0.049	0.049	0.002401	0.0049
110	9.951	10	0.049	0.049	0.002401	0.0049
111	9.951	10	0.049	0.049	0.002401	0.0049
112	9.951	10	0.049	0.049	0.002401	0.0049
113	9.951	10	0.049	0.049	0.002401	0.0049
114	9.951	10	0.049	0.049	0.002401	0.0049
115	9.951	10	0.049	0.049	0.002401	0.0049
116	9.951	10	0.049	0.049	0.002401	0.0049
117	9.951	10	0.049	0.049	0.002401	0.0049
118	9.951	10	0.049	0.049	0.002401	0.0049
119	9.951	10	0.049	0.049	0.002401	0.0049
120	9.951	10	0.049	0.049	0.002401	0.0049
		Totals	4.13	4.13	0.16572	0.413

Appendix C. Arduino Code showing an update for the delay of 1 hour

```
void loop() {
  float pH_value = readPH();
  displaypHValueLCD(pH_value);

  // send to NodeMCU
  value =  dtostrf(pH_value, 4, 2, buff2);  //4 is minimum width, 2 is number of decimal places
  valueString = valueString + value + ",";
  nodemcu.println(valueString);
  valueString = ""; //reset the valueString
//  delay(2000);
  delay(3600000);  // 1 hour wait
```

Appendix D. Request Letter to Acquire Buffer Solutions

DLEAMNOR EURAZE CAWALING & MARK ANTHONY OCCEÑA
University of the Philippines Visayas
Miagao, Iloilo, 5023
09489882710 | 09054957819
dmcawaling@up.edu.ph | meoccena@up.edu.ph

May 03, 2023

Prof. KURT WALDO E. SY PIECO
Chair
Department of Chemistry
College of Arts and Sciences
University of the Philippines Visayas
Miagao, Iloilo

Subject: Request to acquire buffer solutions

Dear Prof. Sy Pieco,

We, Dleamnor Euraze Cawaling and Mark Anthony Occeña are fourth-year B.S. Computer Science students from the University of the Philippines Visayas taking our CMSC 198.2 - Special Problem II. For this course, we have been developing a mobile application that integrates a pH level monitoring and alarm system, and fish farm inventory to improve aquaculture practices.

In line with this, we are writing to formally request for buffer solutions in the Chemistry laboratory to be used to calibrate and test the accuracy of our pH sensor used in our project. Specifically, we would like to request for acidic, basic, and neutral solutions and use them during our system testing within the month of May 2023.

We would be grateful if you could let us have the necessary buffer solutions during the calibration and testing process of our system. We are willing to follow any guidelines or protocols that your department requires. We would also like to assure you that we will properly dispose the solutions with the guidance of the laboratory technician.

Please let us know if there are any requirements associated with this request. We are more than willing to comply with such regulations to complete our project.

Thank you!

Sincerely,

Dleamnor Euraze M. Cawaling
Researcher

Mark Anthony E. Occeña
Researcher

Noted:

Prof. Christi Florence C. Cala-or
Subject Adviser