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Master's Thesis

Analysis of an IOT Based Water Quality Monitoring System for Fish Farms

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ANOTATION

In this paper “Analysis of an IOT Based Water Quality Monitoring System for Fish Farm” discusses about the development of a prototype for monitoring water quality of the fish pond using IoT technology and further analysis of the water quality based on specified thresholds. Firstly, in the light of literature review, a comprehensive analysis on the existing system of water quality monitoring system is conducted. The existing possess number of limitations, so a new system for monitoring water quality monitoring system is proposed. Following the trends, the critical parameters for the water quality monitoring system is identified. For optimal performance, detailed assessment of the sensors required is conducted. Then, prototype is developed for efficient quality monitoring. Finally, the cloud services are used for visualization and analysis of the different water samples.

The work was made in English and consists of 78 pages without supplements, 37 images, 7 tables, and 28 information sources.

ABBREVIATIONS

USB: Universal Serial Bus

IoT: Internet of Things

IDE: Integrated Development Environment

TDS: Total Dissolved Solids

DO: Dissolved Oxygen

NTU: Nephelometric Turbidity Unit

PPM: Parts Per Million

RAM: Random Access Memory

CPU: Central Processing Unit

ADC: Analog to Digital Convertor

GPIO: General Purpose Input Output

UART: Universal Asynchronous Receiver Transmitter

SPI: Serial Peripheral Interface

I2C: Inter-integrated Circuit

ESP-IDF: Espressif IoT Development Framework

OS: Operating System

MQTT: Message Queuing Telemetry Transport

Contents

INTRODUCTION

Fish farming is a growing industry that holds potential, for economic growth particularly in developing countries. To support the development of this industry it is crucial to implement measures with one of the critical steps being the continuous monitoring of water quality. Improper management of the water quality of the fish farm will hurt the growth and health of the fish leading to many health risks. Since water is very essential element in all living organisms and has multiple purposes including drinking, cooking, etc... it is very important to monitor the quality of the water in every source. To protect the health of humans as well as other organisms, we should ensure the proper quality of the water. Neglecting water management can have consequences on both human health and the overall well-being of other living beings. Therefore, maintaining high-quality water is of importance. In the context of fish farming any changes in the chemical properties of water can pose significant risks to fish health. Regularly checking and monitoring water quality, in fish ponds are tasks that should not be overlooked. Nowadays some advancements greatly assist in the management of water resources. This has made it much easier to address and eliminate water pollution, in fish ponds, which ultimately has an impact, on the agriculture industry.

The essential goal of this project is to propose a system to monitor the quality of fish pond water to control water pollution and various other factors with the assistance of IoT. The depth of the water pollution can be identified by estimating the water parameters like turbidity, total dissolved solids, variance in pH, etc... as the contrast in the values of these parameters implies the presence of pollutants. These parameters are detected by chemical laboratory tests, where the equipment is always stationary and samples are to be taken to the laboratories. Thus, it is a manual system with a tedious and time-consuming process. Along with identifying the degree of pollutants, many other factors must be considered. So that the farmers can take necessary actions to avoid the death of fish. These sensors accept the data using various sensors and send these collected data to a microcontroller for processing. The system utilizes the features provided by the Cloud. The data collected is transferred to the cloud and there the data processing functionalities are performed. The analysed data is made available to the farmers and whenever the value monitored breaks the threshold the system provides a notification through a mobile phone. Also, water pumps accompany the system in which one of the pumps takes water out when the turbidity and total dissolved solids value goes above the maximum

threshold and the other takes water in when these values decrease. The farmers will be notified about the changes that occur in the values of each parameter we are collecting. The suggested project utilizes ESP32, which is an open-source development kit and firmware designed for developing IoT products. It consists of firmware that operates on the ESP32 Wi-Fi system-on-chip developed by Espressif Systems, and hardware that is built on the ESP-12 module. Sensors are connected with ESP32 Microcontroller and it needs to be programmed. It is done with the help of Arduino IDE. After that, the power is supplied to the prototype by using a type B USB connector. This efficient system helps the farmers to monitor and manage their fish farm. It will overcome the limitation of the existing system by reducing the time and labour.

The main aim of the thesis is to develop a Real-time system to measure and monitor the water quality parameters of a fish farm by using an IoT platform.

Task For the Thesis

- Comprehensive analysis of the existing water quality monitoring system and finding its importance and weakness of the existing system in the light of literature review.
- Analyzing and identifying the critical water quality parameter directly affecting the growth and health of a fish in fish farm.
- Detailed assessment of sensors that can be used for the optimal performance of the fish farm monitoring system.
- Developing a prototype for monitoring the quality of water in fish farms that aids the efficient operation of fish farms.
- Incorporating visualizations techniques to analyze critical parameters.
- Analyzing and monitoring the water quality through diverse water sample testing.

1. ANALYSIS OF THE LATEST IOT-BASED WATER QUALITY MONITORING TECHONOLOGIES

Water quality monitoring research has been a field, for a period. With advancements new features are emerging in the automation of water supply. Numerous researchers have been diligently working to develop automated systems that monitor parameters to enhance water quality. Several studies discuss these advancements and ongoing research in IoT-based water quality monitoring systems. Some of them are as follows:

One notable study titled "IoT-based Water Quality Monitoring System and Evaluation" by S. A. Hamid, A. M. A Rahim, S. Y Fadhlullah, S. Abdullah, Z. Muhammad, and N.A.M Leh [1] describes an IoT-based water quality monitoring system that employs sensors to track parameters, like pH levels, turbidity, dissolved oxygen and temperature in time. The data collected by these sensors is wirelessly transmitted to a server via a gateway. Additionally, a web-based dashboard is utilized to present the data and generate alerts if certain thresholds are surpassed. The article provides an explanation of the components, both hardware and software that make up the system. It covers the sensors, IoT gateway, and web-based dashboard as the communication protocols used for data transfer, between them. The system's performance was evaluated through experiments conducted in a water tank proving its accuracy in monitoring and controlling parameters. Additionally, a comparison is made with water quality monitoring systems to highlight the advantages of utilizing technology. This system has applications in settings such as water treatment plants, swimming pools, and aquariums. Its time monitoring and control capabilities contribute to safeguarding health by ensuring optimal water quality conditions.

The research paper titled "IoT-Based Smart Monitoring System for Fish Farming " authored by A. Ramya, R. Rohini, and R. Ravi [2] introduces a monitoring system specifically designed for fish farming using technology. The system incorporates microcontroller-based maintenance of fish ponds with the help of sensors. It enables monitoring of parameters like water level, temperature, pH level, dissolved oxygen content, and ammonia levels within the pond environment. The collected data is wirelessly transmitted to a server via a gateway for analysis and processing. Furthermore, users can remotely. Control their fish ponds, through a mobile application. The system includes both hardware and software components as communication protocols, for data transfer between these components. To evaluate its performance experiments were conducted in a fish pond. The results demonstrated the systems

monitoring and control of parameters ensuring the fish's healthy growth. This highlights how IoT technology can be beneficial in fish farming by increasing productivity improving efficiency and reducing labour costs. Fish farmers can remotely. Manage their ponds using this developed system, which ultimately enhances the profitability of their farms while ensuring the well-being of the fish.

In a publication by A.A.S. Chowdhury, Y. Arafat, and M.S. Alam titled "IoT GSM Based Controlling and Monitoring System to Prevent Water Wastage, Water Leakage and Pollution in the Water Supply "[5] they propose a system that utilizes the Internet of Things (IoT) technology along with Global System for Mobile communication (GSM) to monitor and control water wastage, leakage and pollution in water supply systems. This innovative solution incorporates sensors, a microcontroller, a GSM module for communication purposes well, and a web-based interface, for easy access and management. The sensors are responsible, for detecting the levels flow rate and quality of water. This information is then processed by a microcontroller, which adjusts the water supply system accordingly. In case there are any deviations from the parameter's notifications are sent to the authorities through a GSM module. Additionally, a web-based interface enables monitoring and control of the system. The authors of the research argue that this proposed system can effectively prevent water wastage, leakage, and pollution by offering time monitoring and control capabilities. Ultimately it aims to improve water management and conservation efforts.

The article titled "IoT-Based Water Quality Monitoring with Android Application" has been authored by R.C.G., T.V.A., Liloja, and M. Shahzad [7]. It introduces an IoT-based system for monitoring water quality that can be accessed through an Android application. This system includes sensors as well as a microcontroller and Wi-Fi module. The sensors measure parameters like pH level, turbidity, and temperature while the microcontroller processes this data before sending it to a cloud-based server. The Wi Fi module facilitates communication between the system and an Android application which allows time remote monitoring of water quality parameters. According to the authors, this system has the potential to enhance water quality monitoring by providing data, on parameters and enabling remote access and control via an Android application. The system can also help detect water quality problems minimizing any negative impacts, on human health and the environment. To sum up, this proposed system has the potential to bring improvements to water management and conservation efforts by addressing the issue of monitoring water quality.

The article titled "Development of IoT for Automated Water Quality Monitoring System" by R. P. N. Budiarti, A. Tjahjono, M. Hariadi, and M. H. Purnomo [8] introduces an Internet of Things (IoT) based system for monitoring water quality. It incorporates sensors, a microcontroller, and a web-based interface. These sensors measure parameters like pH levels, turbidity dissolved oxygen level, and temperature in the water while the microcontroller processes this data and sends it to a cloud-based server. Through the web-based interface users can remotely monitor real-time information about these water quality parameters. The main objective of this proposed system is to enhance water quality monitoring by providing data on parameters and promptly identifying any issues that may arise to prevent negative impacts, on human health and the environment.

To conclude this literature review has extensively explored aspects of IoT-based systems for monitoring water quality. The analysis showed that these systems have the potential to tackle the increasing worries, about water pollution and ensure the presence of pure water resources. It emphasized the elements of IoT-based systems for monitoring water quality, which include sensors, communication networks, data processing, and analysis platforms. These systems allow for collecting data in time monitoring from a distance and timely identification of water quality factors, like pH level, temperature, dissolved oxygen content, turbidity, and chemical pollutants.

1.1. Research of existing water quality monitoring systems

System Study is the process of gathering information regarding the business requirements, analyzing the facts, identifying the problem, and using this information to develop a new system or to suggest improvements to the system that already exists. The main aim of examining the situation is to improve the system through better strategies. It defines the requirements and the problems that the client is attempting to describe. System Analysis is a procedure of examining the gathered information, identifying the issue and using this data to either develop a totally new system or to complete the further enhancements of the current system.[2] A proper system study includes the way to improve it through better strategies. Here, the system study is about the water quality monitoring system for fish farming. Initially, the problem faced by the farmers is identified, then information is gathered and using this information, a solution is made to either improve the existing system or develop a better system

to solve the problems. In the context of water quality monitoring system for fish farming, the problem faced by the farmers include bad quality of water, changing weather conditions, death of fish etc.… To eliminate these problems there are many manual solutions that include tiresome processes. Further studies on this problem, helped to come up with a better solution that incorporates technicality.

Existing System

The existing system regarding water quality monitoring system involves the manual collection of water samples from ponds by individuals, who then transport these samples to laboratories for analysis. This process is both time-consuming and expensive, as it requires regular travel to specific locations and the payment of fees for each test conducted in the laboratory. Additionally, since the laboratories are stationary, it may not be convenient for farmers to reach them, particularly if they are at far away remote locations. Furthermore, this process requires a significant amount of human labour. The individuals responsible for collecting water samples and transporting them to laboratories must do so regularly, which can be a challenging task. Additionally, routine checks on water levels in the ponds also require frequent monitoring, which again adds to the burden of manual labor. The farmers need to keep a record of the data collected, and after a specific interval, processing needs to be completed. Through this data processing, inferences are made and that gives farmers proper information about the pond. However, the problem with this traditional technique is that there is no real-time monitoring of the water since the data is collected and stored for specific intervals of time for processing.[2]

Lately, there are many automated systems equipped with new technologies are being under use. However, these automated systems are not efficient enough to check all the parameters of the water quality together. This kind of existing system checks the value of very few numbers of parameters, it cannot incorporate many numbers of sensors. An efficient system requires multiple systems including various sensors. So, it will be difficult for the farmers to include multiple systems which will increase the cost of using the system. These problems together will make the farmers unable to afford this automated system.

The existing manual system of water quality monitoring is not efficient. It is very costly and requires more manual work. By using the existing system, there are chances for the system to provide erroneous data and also can cause great delays in giving measurements. These disadvantages will affect the accuracy of the system. Therefore, using the technology and

innovations, a new system that can reduce cost and increase efficiency is proposed. With this system, human labour can be reduced to an extent.

1.2. Disadvantages of existing system

The existing system has many disadvantages that put forward the need for a new efficient system. Some of the disadvantages include; that it requires frequent sampling and analysis, which can be a time-consuming process. It can be expensive, particularly if they require regular travel to specific locations and payment of fees for each test conducted in the laboratory. It requires human labour. It is difficult to identify water quality issues in real-time or respond quickly to emerging issues.[6] Also, this system is susceptible to errors and inconsistencies caused by human factors. Technology-incorporated automated systems available are also not efficient enough to meet the needs of farmers. The available systems do not even have all the necessary sensors. So multiple systems with different sensors need to be used which will enlarge the system and also increase the cost to a level that will become uneconomical. So, when these systems come to be in use, it will cause economic losses. And further, it leads to economic instability.

2. STUDY OF WATER QUALITY PARAMETERS IN FISH FARM

The aquaculture industry is a growing billion-dollar sector driven by the increasing demand, for water. As the global population continues to rise so does the need for food supplements and seafood. Fish farmers have the task of meeting this demand, which requires the management of water quality in their ponds. However, managing water quality in this industry poses challenges. One significant issue is water quality, which can lead to diseases, hinder fish growth, and even result in losses for farmers. To address these challenges fish farmers have solutions at hand. One important approach involves real-time monitoring of water quality parameters.

Water quality parameters play a role in ensuring fish farming practices in ponds. Monitoring and maintaining levels of these parameters are essential for conditions that support fish growth and reproduction. Various parameters are commonly measured to create an environment for fish growth and sustainable aquaculture practices. By monitoring these parameters and taking actions based on them farmers can ensure a productive aquatic environment that promotes optimal conditions, for fish growth and sustain aquaculture practices. These parameters act as indicators of the well-being and suitability of the water, for supporting life, especially fish. Various parameters are commonly evaluated to ensure conditions for the growth and reproduction of fish in pond environments.[9]

- Temperature: Temperature plays a role, in influencing the metabolic rates, physiological functions and feeding behaviours of fish. Each fish species has temperature requirements for their growth and reproductive processes. Hence it is vital to maintain temperature levels in the pond.
- Dissolved Oxygen: It is essential for the respiration and decomposition of matter in the water. Insufficient dissolved oxygen content can result in reduced growth rates and even mortality among fish. Regular monitoring helps prevent oxygen depletion issues.
- Potential of hydrogen: The pH level significantly influences mineral solubility and availability in water. Each fish species has its preferred pH range with 7.4 being a value that matches their blood pH level. Ensuring pH levels is very important for better health and growth of the fish.
- Nitrogen Compounds: The presence of compounds can be detrimental to fish potentially leading to their demise. Nitrate and ammonia are examples of compounds that should

be taken into consideration. To prevent it from happening, proper monitoring should be done.

- Total Dissolved Solids (TDS): refer to the presence of minerals and salts dissolved in water. Any increase in salt content can have effects on fish. It is essential to maintain appropriate TDS levels in the water. Salinity, which measures salt concentration is crucial for fish species that have adapted to water conditions. Whenever the salt in the water increases, it will affect the fish physically, so it is important to maintain TDS in the water
- Turbidity: It is the cloudiness or haziness of water caused by suspended particles. Excessive turbidity can impact penetration. Reduces photosynthesis in aquatic plants, which in turn affects the entire pond ecosystem. Monitoring and managing turbidity levels are vital for keeping water clarity intact and supporting an environment.

Many more parameters should be considered such as nitrogen, and phosphorous that play a role in the productivity of the fish. Regular assessment helps manage inputs and prevents any potential issues, with water quality. While considering the water quality of the fish pond, we should properly monitor the necessary parameters. Otherwise, it can lead to oxygen depletion and other critical issues.[4]

2.1. Analysing critical water quality parameters for monitoring

In the proposed system, based on the availability of the sensors in the market and depending on the feasibility, from the above parameter list, Temperature, pH, water level, TDS, and Turbidity are measured. For measuring these parameter values, particular sensors are available. Here, temperature, pH, and water level are the most vital parameters that need to be monitored frequently. Measuring TDS and turbidity helped in understanding further Dissolved oxygen content. Using the above parameters, the quality of the water source can be effectively measured.[20]

2.1.1. Turbidity explanation in aquatic ecosystem

Turbidity is the cloudiness of the liquid caused by the particles dissolved in the water. These particles will make the water look cloudy. The measurement of turbidity plays a vital role in checking the water quality. Higher turbidity degrades the quality of water thus affecting the

growth and life of fish. Higher scattering implies higher turbidity. Turbidity is measured using a unit called NTU (Nephelometric Turbidity Unit). It impacts the amount of light that can penetrate water thus affecting the depth at which light can reach. Turbidity has both indirect consequences, on organisms. Maintaining levels of turbidity is crucial, for preserving an aquatic ecosystem promoting the well-being of fish and other aquatic creatures, and ensuring the efficiency of water treatment procedures.[17] Table 2.1 shows the turbidity level required for different species of fish say Tilapia, Trout, Catfish, Salmon.

Table 2.1

Turbidity level applicable to different species of fish

TYPE OF FISH	TURBIDITY (NTU)
Tilapia	<50
Trout	<10
Catfish	<50
Salmon	<10

2.1.2. Potential of hydrogen explanation in aquatic ecosystem

pH, also known as the potential of hydrogen is a way to measure how acidic or alkaline a solution is. It uses a scale from 0, to 14 to indicate the concentration of hydrogen ions, which determines if the solution is basic or acidic. When the pH value is 7 it means the solution is neutral. If the value goes below 7 it indicates acidity. If it goes above 7 it signifies alkalinity. In environments like fish ponds and other aquatic settings, pH plays a role in influencing mineral solubility and nutrient availability. Different fish species have their preferences when it comes to pH levels and any deviations can impact their growth and overall well-being. For example, acidic or alkaline conditions can adversely affect fish health. PH levels are interconnected with water quality factors like dissolved oxygen. It's essential to maintain a pH range to achieve balance in the ecosystem and support the health and development of organisms. Regular

monitoring and adjusting of pH levels contribute significantly to ensuring productive environments that provide optimal conditions, for fish and other forms of aquatic life. [19] Table 2.2 shows the pH level required for different species of fish say Tilapia, Trout, Catfish, Salmon.

Table 2.2

Potential of hydrogen level applicable to different species of fish

TYPE OF FISH	pH
Tilapia	6.5-9.0
Trout	6.5-8.0
Catfish	6.5-8.5
Salmon	6.0-8.0

2.1.3. Total dissolved solids explanation in aquatic ecosystem

It is a measure of the concentration of inorganic and organic substances dissolved in water. TDS is commonly expressed in parts per million (ppm). Monitoring TDS is important for assessing the overall quality of water, as high or low levels can affect various aquatic environments, including aquaculture. High TDS values may indicate an accumulation of salts, leading to salinity issues harmful to organisms. In contrast, low TDS levels might suggest a lack of essential minerals. Balancing TDS levels is crucial for maintaining a healthy and sustainable aquatic environment while meeting the diverse needs of human water consumption.[16] Table 2.3 shows the TDS level required for different species of fish say Tilapia, Trout, Catfish, Salmon.

Table 2.3

TDS level applicable to different species of fish

TYPE OF FISH	TDS (ppm)
Tilapia	300-1,000
Trout	150-500
Catfish	300-1,000
Salmon	300-1,000

2.1.4. Temperature explanation in aquatic ecosystem

The temperature of a fish pond plays a role in the well-being and behaviour of aquatic organisms. Fish body temperature is mainly regulated by the surrounding environment. Different fish species have varying optimal temperature ranges. It is essential to maintain conditions, for their metabolic processes, growth, and reproduction. Temperature directly affects the metabolic rate of fish; higher temperatures generally speed up their metabolic functions, which in turn affect their feeding patterns and growth rates. On the other hand, lower temperatures can lead to activity and metabolism in fish potentially impacting their ability to digest food effectively. Temperature also has an impact on the dissolved oxygen levels in water. Warmer water tends to hold dissolved oxygen which can cause stress or even mortality among fish if oxygen availability becomes inadequate. Moreover, temperature plays a role in determining when and how successfully fish breed since certain species have temperature requirements, for successful reproduction. Fish pond managers regularly monitor and manage water temperature to ensure it falls within the appropriate range for the targeted fish species.[15] Table 2.4 shows the temperature level required for different species of fish say Tilapia, Trout, Catfish, Salmon.

Table 2.4

Temperature level applicable to different species of fish

TYPE OF FISH	TEMPERATURE (°C)
Tilapia	25-30
Trout	10-20
Catfish	25-30
Salmon	10-14

2.2 The current framework of automated water quality monitoring system

A new system is being suggested to overcome the limitations of the system. The main goal of this proposed system is to create a water quality monitoring system, for fish farmers. It will enable them to measure water quality parameters in their fish ponds. The system will consist of an esp32 board, which will act as the control unit along with sensors such as pH, turbidity, TDS, and temperature sensors. These sensors will be connected to the ESP32 MCU board. Used to detect the pH level, turbidity level total dissolved solids (TDS), and temperature of the water in the pond. The values of these parameters will be continuous. Transmitted to a cloud-based platform, for analysis. The cloud then processes the data and with the help of this data, notifications are sent to the farmers. Notifications work based on the threshold set for all the parameters. There are advantages, to using this system for monitoring water quality in fish farming compared to methods. Firstly, it provides real time data allowing fish farmers to quickly respond to any emerging issues and take actions to maintain the health of their fish. Secondly, the use of sensors eliminates the need for labor. Travel to specific locations thus reducing costs and increasing overall efficiency. Thirdly the system being cloud-based allows for data analysis and visualization enabling fish farmers to make decisions based on the data collected.

Overall implementing this water quality monitoring and notification system is a step, towards improving fish farming practices promoting sustainability, and ensuring the well-being of fish in ponds. While there may be some limitations that need addressing in the future despite

this system being proposed. In this proposed system, the user will be notified about the variations in the values of each parameter under consideration. To an extent, these push notifications aid users in getting information about parameters. But beyond this limit, it needs to be addressed properly. So, the lack of a proper user interface is one of the main disadvantages of this system. Also, whenever the variations occur, manual action is required which further requires time and labor, with the help of complete automation we can overcome these limitations.

2.2.1 Advantages of Proposed System

Over the traditional water quality monitoring system for fish farming, the proposed automated water quality monitoring system has several advantages. It can collect real-time data, so immediate actions can be taken based on the results. Fish farmers will get information about the chemical and physical parameters that will help the farmers to respond quickly. Farmers need to take necessary measures to ensure the growth and health of the fish. With the help of sensors, the need for the manual labor and travel can be reduced. It also reduces the total costs and increase the efficiency. The proposed uses cloud-based services that allows easy data analysis and visualization. Visualization includes charts, gauge, list etc... Water quality monitoring and notification system improves the fish farming practices and ensure the growth and health of the fish in the water body. Therefore, the use of automated water quality monitoring system can help farmers improve their fish farming industry to a great extent. The IoT-enabled system ensures continuous, real-time monitoring of water quality parameters. This allows the timely action by the farmers dealing with irregularity in parameters. Traditional water quality monitoring methods often involve manual water collection and laboratory analysis, which costs high. The automated IoT system reduces the need for manual intervention. With sensors providing real-time data directly from water sources, the system offers a high level of accuracy. This accuracy is crucial for making informed decisions regarding water resource management. The system's ability to detect anomalies and issue alerts in real time serves as an early warning system. This is invaluable in preventing and mitigating the impact of water contamination events. By providing comprehensive insights into water quality, the system contributes to environmental conservation efforts. Timely identification of pollution sources and effective management practices can help protect ecosystems and biodiversity. The user interface of the system is designed to be accessible to a wide range of stakeholders. This includes water management authorities, environmental agencies, researchers, and even the

general public, fostering transparency and community engagement. Additional sensors can be easily integrated into the network to expand monitoring capabilities as needed. The remote monitoring and control features enable authorities to manage water quality from a centralized location.

2.2.2 Analysing a comprehensive feasibility study of the project

The term "feasibility" pertains to determining the likelihood of a project's success and devising strategies to overcome obstacles. A feasibility study serves the purpose of highlighting both the pros and cons of a project and providing answers to inquiries regarding available resources and required equipment. This step holds importance in assessing a business concept since it aids in identifying risks and challenges at an early stage. By an active approach and addressing these issues, the chances of success for the project can be increased. The feasibility study typically includes three main sections, and it is important to determine the feasibility of a project before attempting it. The project aims to solve the limitation of a manual system of water quality monitoring. By monitoring and controlling pond water, users can ensure the proper growth of fish, by which farmers can improve their business. The goals and tasks of the project include reading the sensor data, sending data to ESP32 MCU, from ESP32 sending data to the Arduino cloud, and processing and analysing the data collected. By using the notification module accompanying the system, users can get the parameter values. These notifications are sent based on the threshold value set depending on the size of the pond or the type of fish cultivated. When it comes to the availability of the components required to complete the project, most of the required components are available in the market. All the IoT-related components are easy to use and have many purposes other than automation of water quality monitoring. Most of the components have multiple uses. All the technical resources are available on the Internet. To make the working of the components easier, there are many documents available online. Most of the required knowledge is available to the public and has sources where we can get the knowledge. The project aims to solve the problems faced by farmers while using a manual system of water quality monitoring. So, the project has relevance in today’s world. The project targets the upper-middle class and high class in the long-term goal. The overall cost of the proposed system is affordable to the common people. However, the initial cost is a little high, but maintenance is much easier. The project duration is feasible. Within 3 months the project can be completed. The hardware connection and software development require a maximum of 2 months. The project can be completed in person there is no requirement for a

team. The hardware soldering and software coding can be done by person. The proposed system is cost-efficient. All the components are available in the market. Also, it can be bought online. This research is centred around evaluating the expenses associated with a project, including capital costs, operational costs, and miscellaneous expenses. However, this assessment can only take place after completing two components; the study and the operational study. The economic feasibility analysis encompasses calculating all costs to determine the profitability of the project. This evaluation aids project owners, in making a decision, on whether to proceed with establishing the project or terminate it. In this project, the initial cost for sensors is high, but compared with the summed-up cost of manual testing, it is feasible. All other platforms used are free of cost.[3]

3. ANALYSIS OF THE SYSTEM ARCHITECTURE AND SPECIFICATIONS

System configuration refers to the specification of the system under development, from the hardware to the software and processes that run in a system. For the development of the entire system, proper system configuration should be maintained for easy development and maintenance. While working on a system, configurations should be up to date. Otherwise, there are chances where the system can go wrong very easily. In the case of a water quality monitoring system for fish farming, there are many hardware and software components required to complete the development of the system.

Hardware components include the simple connecting wires to the most prominent microcontroller. Sensors like pH sensors, turbidity sensors, TDS sensors, and temperature sensors complete the monitoring module by performing their respective function of monitoring water quality. Together with this monitoring module, there exists a pumping system that works whenever the parameter values breaks the threshold. To make the pumping system work, the system makes use of 8-channel relay and submersible pumps. 8-channel relay is used to control several appliances with a large current. The relay can be used for controlling the microcontroller. Submersible pumps perform the pumping with the help of a relay module. The pump is submersed into the water to be pumped. The water quality system works with minimum personal system configurations.

Software components include Arduino IDE and Arduino Cloud. Arduino IDE is used for the programming of the ESP32 Microcontroller with the sensors used. Arduino IDE uses C and C++ programming languages for programming. Through the programming code, we can specify how the systems work that is how the sensors should act. The data collected or captured is fed to the Arduino Cloud. Using a cloud system helps the users to easily process the data.

3.1. Hardware Requirements

The main hardware components required for the implementation of the system are:

- Micro-controller : NodeMCU ESP32
- Liquid pH Sensor
- Temperature Sensor : DS18B20
- Turbidity Sensor

- TDS Sensor
- Ultrasonic sensor
- Relay Module : 8-channel relay board
- Submersible Pump

3.1.1. Overview of ESP32 microcontroller architecture

In the developing phase IoT industry, ESP32 is the most prominent dual-core microcontroller that is considered. ESP32 is developed as the successor of ESP8266 with many additional features. The main advantage offered by ESP32 is the low power consumption. It consists a power management system that helps the microcontroller to run on very low power, that makes it ideal for battery-powered IoT devices. SPI, UART, DAC, ADC, and I2C are the wide range of interfaces and peripherals included in the ESP32. A wide range of development environments including the Arduino IDE, Micro python, and ESP-IDF is supported by it. Using different programming languages, it will very easy to develop an IoT based prototype with ESP32. Along with hardware capabilities, ESP32 provides strong security with the help of secure boot and secure flash encryption feature that helps the data from being tampered. Thus, it can be used in security applications such as medical and financial systems. Advantages of ESP32 Microcontroller include low power consumption, built-in connectivity options, wide range of interfaces for IoT applications. It is developed by Espressif Systems using powerful IC. ESP32 has a broader range of capabilities.[21]

With a clock speed of 250 MHz, the ESP32 microcontroller has the power of dual of dual Tensilica LX6 processors. ESP32 is a multitasker with the capability of executing multiple tasks that are even complex. This processor incorporates efficiently integrated Wi-Fi and Bluetooth. Using the latest 802.11 b/g/n/e/i standards, the ESP32 ensures proper network connectivity and communication. It saves a lot of energy with its feature of low power consumption. With GPIO, SPI, I2C, UART, and other features, the system can customized easily. Moreover, the ESP32 Microcontroller is highly adaptable allowing the system to connect with a wide range of sensors and other devices. With the help of an efficient power management system makes sure that the microcontroller functions properly and extends the lifespan of the device. It has multiple power modes that make way for optimal energy consumption. Since the ESP32 has compatibility with Arduino IDE, ESP-IDF and Micropython, programming the microcontroller is effortless. Also, this system provides a wide range of libraries for multiple

sensors, which makes the work of the developer quite easier. Figure 3.1 depicts the diagram of the ESP32 Microcontroller.

Figure 3.1 ESP32 Microcontroller

The ESP32 microcontroller provides a power management feature and has various power modes to optimize energy consumption. Since the system offers a wide range of tools and libraries for coding, it is trouble-free for beginners and experienced developers to develop a system and prototype. Security is uncompromised in the ESP32 System. For that, it uses secure boot and flash encryption techniques that enhance the integrity, and confidentiality of the firmware and also protect the data from unauthorized access. Nowadays, to increase the easiness of development, ESP32 has support from communities that contribute facilities like tutorials, documentation, and open-source projects. Home automation and monitoring systems are the main areas where these innovations are adopted. the growth of this collaborative environment is highly accelerated so that becomes a robust solution for IoT applications. Its multi-faceted features such as dual-core architecture, efficient peripherals, and low power consumption make it an excellent choice for developers to give their ideas a life.

Features:

- Dual-core processor: Dual-core Tensilica LX6 processor that helps in the multitasking.
- USB: micro-USB port for power supply, and can be used lately for programming and

debugging.

- Built-in connectivity: Built-in WiFi, Bluetooth, and Bluetooth Low-Energy (BLE) facilities that enable effortless connection with sensors and devices.
- Power: 5 volts provided through micro-USB port.
- Low power consumption: Power management system that enables low power consumption and makes it ideal for low-powered systems.

3.1.2. Temperature sensor description

DS18B20 is a liquid temperature sensor that can be used with any microcontroller, it uses a single digital pin. It is used for checking the temperature of chemical solutions or can be used in mines or soil. It has a robust making structure that makes it suitable for challenging environmental situations. To make the system easy to mount, the sensor is made as waterproof. It has a measurement range of -55 degrees Celsius to +125 degrees Celsius. Every sensor has a unique address. Also, it has an accuracy rate of +/-5 degrees Celsius. To transfer data that is collected it makes use of one digital pin of the microcontroller so, it becomes an efficient choice for measuring temperature. DS18B20 liquid temperature sensor is widely known for its accuracy and ease of use. With minimal hardware requirements, it provides precise temperature measurements. It is manufactured by Maxim Integrated Products. It is a one-wire digital sensor. Figure 3.2, 3.3 depicts the hardware diagram of DS18B20 Temperature Sensor

Figure 3.2 Temperature sensor probe

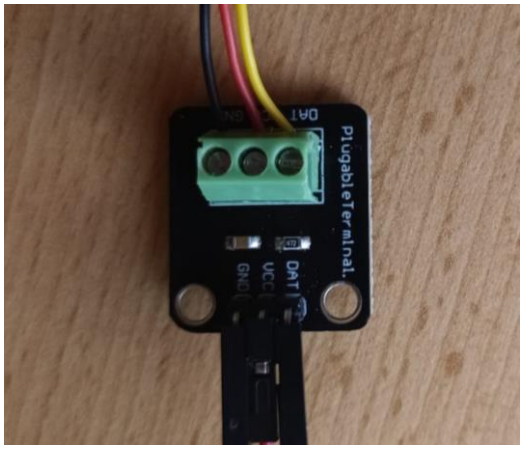

Figure 3.3 Temperature sensor board

Communication protocol used by the DS18B20 liquid temperature is One-wire communication protocol. With the help of this protocol, multiple DS18B20 sensors can be connected to a microcontroller. It can be used in situations where there is a limitation in space. It is very small in size and is also waterproof and made of stainless steel that makes it easy to use. It can operate and measure wide range of temperature from -55 degrees Celsius to +125 degrees Celsius. It also has an accuracy rate of +/-5 degrees Celsius. From the industrial process to the scientific research, the temperature sensor has many practical applications. Since it is waterproof, it can be used for multiple processes without compromising its functionality and can monitor temperature precisely. The stainless-steel casing enhances the durability of the sensor in challenging conditions. The resolution of the sensor is programmable. having option range from 9 to 12 bits. higher resolution implies more accurate temperature readings. But it requires longer conversion time. Main advantage offered by the sensor is low power consumption. So, it is suitable for battery-powered applications. It can connect with any microcontroller and can also be integrated into any system very easily. It is cheap compared to other temperature sensors. Features such as one-wire protocol, low power consumption, waterproof construction and many more increased its popularity among the developers. It continues to prove its reliability and effectiveness.[21]

Specifications:

- Measurement range: Temperature measurement range starts from -55°C to +125°C.
- High Accuracy: The sensor has an accuracy rate of ±0.5°C.
- One-Wire Interface: Sensor has a unique address, and can be connected to single digital pin.

- Programmable Resolution: The resolution of the sensor is programmable from 9 to 12 bits, giving the user the flexibility to choose between lower resolution and faster conversion time or higher resolution and slower conversion time.
- Low Power Consumption: Require less amount of power to work.
- DS18B20 can be powered by the data line, which means that it can operate without an external power supply in certain applications.
- Power supply: 3V to 5.5V
- Rugged Construction: Sensor is cased with stainless-steel and is waterproof, so can be used even in harsh conditions.

3.1.3. Ultrasonic sensor description

HCSR04 Ultrasonic sensors find usage in measuring the distance, between objects or detecting their presence. These sensors employ waves to accomplish these tasks. A typical sensor setup comprises a transmitter and a receiver. Here's how it works; The transmitter emits a frequency sound wave typically ranging from 20kHz to hundred kHz. The sensor then measures the time it takes for the sound wave to return after striking an object using this delay to calculate the distance between them. If the receiver receives the returning sound wave it confirms the presence of an object. The calculations rely on determining the speed of waves through the medium they travel in. HCSR04 Ultrasonic sensors find applications in fields such as measuring distances sensing water levels and detecting objects. Industries like robotics, security systems, and automobiles heavily rely on these sensors. Nowadays we often encounter toy cars equipped with a sensor that automatically detects obstacles and adjusts its movement accordingly. These sensors are cost-effective. They have gained popularity due to their reliable output in measuring distances up to 400 cm from as close, as 2 cm.

Features:

- Bandwidth: 40 kHz
- Distance measurement: Used for measuring distance between objects.
- Non-contact operation: Operate without contact between objects.
- Output types: Different analog voltage, digital, or serial output, depending on the specific sensor model.
- Easy integration: This can be integrated into different systems easily.
- High-frequency operation: Operate at high frequencies, usually in the range of 20

kHz to several hundred kHz.

3.1.4. Turbidity sensor description

Turbidity sensors find usage across industries, like water treatment, environmental monitoring, industrial process control, and research applications. These sensors serve as instruments designed to measure the cloudiness or haziness of a liquid caused by suspended particles. These particles can include sediment, silt, clay, microorganisms, and other substances that reduce the transparency of the liquid. Assessing turbidity holds importance in fields such as environmental monitoring, water quality evaluation, industrial processes, and scientific research. The role of turbidity sensors is crucial in quantifying and monitoring these suspended particles effectively while providing data for enhancing and maintaining the quality of water and other fluids.[21]

Water treatment plants and distribution systems heavily rely on turbidity sensors for their operations. These sensors play a role in ensuring that water meets standards concerning clarity and purity. By assessing turbidity levels professionals involved in water treatment can identify issues like the presence of contaminants or inadequate filtration methods. Such vigilance is essential to deliver drinking water with cleanliness, to communities since turbidity acts as an indicator of overall water quality. In monitoring practices, rivers, lakes, and oceans deploy turbidity sensors to evaluate both water quality levels and ecological well-being.

Excessive amounts of cloudiness, in the water, known as turbidity can have effects on ecosystems. It can block sunlight disrupt the process of photosynthesis and upset the balance of these environments. To safeguard and preserve habitats scientists use a method called turbidity monitoring to detect changes in water quality over time. By doing they can take action to protect these delicate ecosystems.

Turbidity sensors work based on principles like nephelometry and absorption. Nephelometry measures the scattered light caused by particles suspended in the liquid. The sensor emits light into a sample. The amount of scattered light is directly related to how cloudy it is. On the other hand, absorption-based sensors measure how much light is absorbed by those suspended particles in the sample. Both methods provide dependable measurements of turbidity; which one to choose depends on application requirements.

Modern turbidity sensors come equipped with features like calibration self-cleaning mechanisms and real-time data logging. Automatic calibration ensures consistent measurements over time while self-cleaning mechanisms prevent sensor fouling that could

interfere with its performance under challenging conditions. Real-time data logging capabilities enable tracking of turbidity levels so that timely action can be taken if deviations, from desired water quality standards occur.[21]

Besides their use, in water monitoring turbidity sensors have found applications in various industries like food and beverage production, pharmaceuticals, and wastewater treatment. These sectors heavily rely on control of turbidity levels to ensure quality assurance and compliance with regulations. To summarize turbidity sensors are tools for monitoring and managing the clarity of liquids across applications. Their capability to provide time and accurate data is invaluable in safeguarding drinking water safety preserving ecosystems and supporting diverse industrial processes. With advancing technology turbidity sensors are expected to become more sophisticated contributing significantly to improved water quality management and environmental stewardship. The main sources of turbidity often include sediment or pollutants. Natural sources comprise erosion from upland areas, riparian zones, stream banks, and channels. Turbidity can also arise from algae growth fuelled by nutrients entering streams through leaf decomposition or other natural decomposition processes. Stream channel movement can release sediment well. Additionally, organic matter from sewage discharges (during treatment plant bypasses can contribute to turbidity levels. Human activities such as construction, mining, and agriculture can also result in sediment concentrations entering water bodies during rainstorms due, to runoff.

Turbidity is typically assessed by using tools either in a lab or, out in the field. The process involves directing light through a water sample and measuring the amount of scattered light. This measurement is expressed in Nephelometric Turbidity Units (NTU) which come in forms. The scattered light there is the turbidity. Lower turbidity values suggest water while higher values indicate clarity, in the water. Figure 3.4, 3.5 depicts the hardware diagram of Turbidity Sensor.

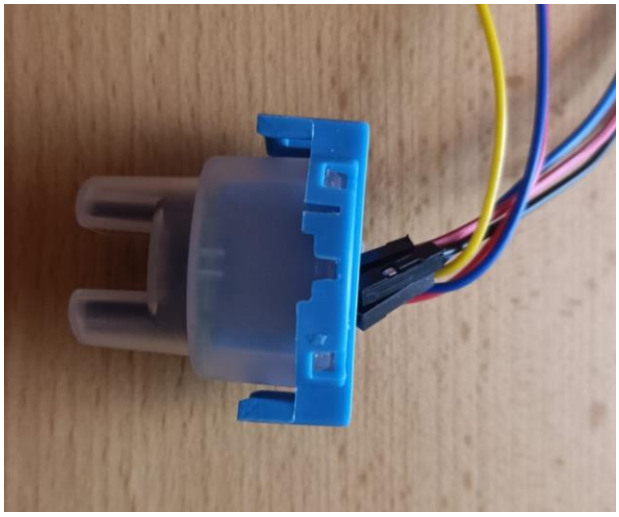

Figure 3.4 Turbidity sensor probe.

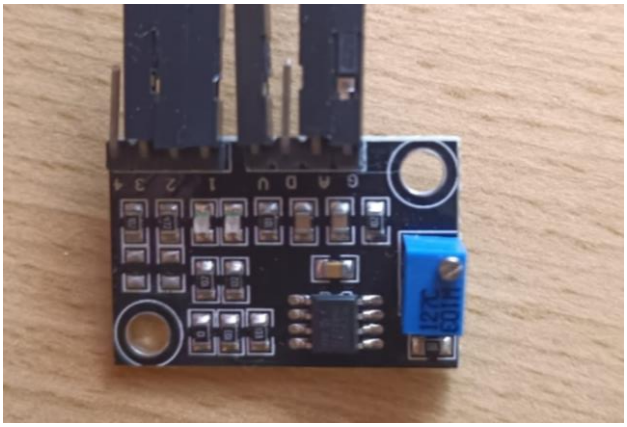

Figure 3.5 Turbidity sensor board.

Specifications:

- Measurement range: Depending on the sensor model, the measurement range of the turbidity sensor can vary from 0 to 10 NTU or 0 to 1000 NTU.
- Accuracy and precision: Just like the measurement range, accuracy and precision also vary depending on the sensor model. However, it offers accuracy and precision in measurement.
- Sensitivity: It explains the sensitivity of the sensor to the size of the particle. If the particle is dissolved completely, it will measure the turbidity more accurately.
- Calibration: Calibration is required to get more accuracy in measurement.
- Output signal: Analog voltage, digital, or serial output are the different types of Output

signals of turbidity sensors. These signals determine the measurement.

- Power supply: It requires a 5 Volt operating voltage.

3.1.5. TDS Sensor descriptions

TDS Sensor measures the total dissolved solids in the given sample. It is used in aquariums, swimming pools and other hydro systems. TDS Sensor is measured by monitoring the conductivity of the liquid. This is correlates with the concentration of dissolved solids. Two electrodes are present in the sensor. It is then immersed into the sample liquid. Through one electrode, electric current is applied and then the conductivity is measured by the other. With the help of calibration factor, the value obtained by measuring the conductivity is converted into TDS readings. The TDS sensor probe is immersed into the liquid. Calibration of the sensor is required to get accurate value. Based on the intended use, it should be calibrated.[21] To complete the monitoring of the TDS value in the liquid, the temperature value of the liquid should also be monitored. For the ease of it, some sensor models have integrated temperature sensor. By measuring total dissolved solids level in the water, we can ensure the safety in drinking water, quality of water in fish pond etc... Figure 3.6, 3.7 depicts the hardware diagram of TDS Sensor.

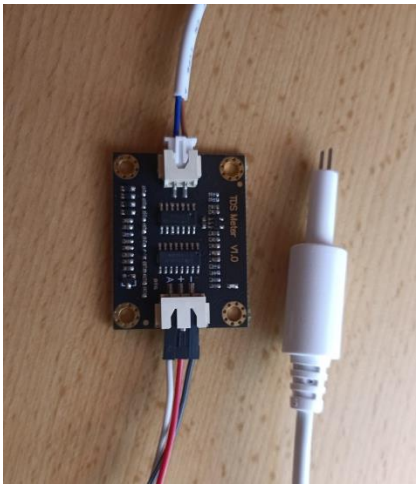

Figure 3.6 TDS sensor probe.

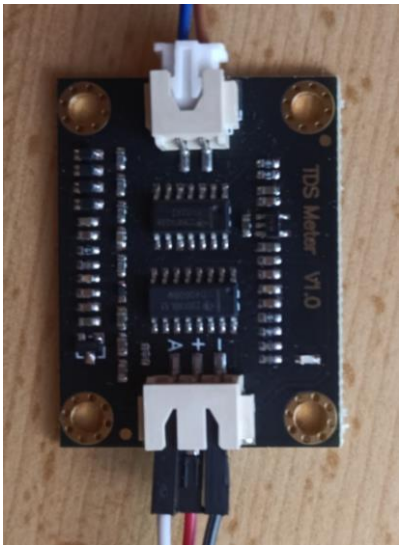

Figure 3.7 TDS sensor board.

Specifications:

- Accurate measurement: Provide accurate measurement from 0 to 10,000 ppm.
- It is very easy to use the sensor, can be integrated into project easily.
- Compact design: Small size of the sensor makes it easy to use.
- Low power consumption: It consume less power, so it can be used in battery-powered applications.
- Construction: It is waterproof and is rust-resistant.
- Adjustment: With the help of calibration, accurate results can be obtained.

3.1.6. pH Sensor descriptions

The analog pH meter is specially designed for Arduino controllers and has built-in simple, convenient, and practical connections and features. It has an LED that works as the Power Indicator, a BNC connector, and a PH2. 0 sensor interface. To make use of it simply connect the pH sensor using a BNC connector. Insert the PH2. 0 interface, into the analog input port. Analog-to-digital conversion (ADC) is employed to convert analog values into ones. A pH sensor is a tool designed for measuring the acidity or alkalinity of a liquid solution. The pH scale, which represents the concentration of hydrogen ions in a solution ranges from 0 to 14. A pH value of 7 indicates neutrality below 7 signifies acidity and above 7 implies alkalinity. Accurate measurement of pH is crucial in industries such as water treatment facilities, laboratories, and industrial processes to maintain conditions. The construction of a pH sensor

involves two components; a glass electrode and a reference electrode. The glass electrode serves as the sensing element that detects changes, in hydrogen ion concentration. It functions as a membrane allowing hydrogen ions to pass through. On the other hand, the reference electrode, which is usually made from a non-reactive material provides a stable reference potential against which the pH electrode can measure the sample.

The operation of a pH sensor relies on principles derived from electrochemistry. When the glass electrode comes into contact with a liquid it generates a difference based on the hydrogen ion concentration in that solution. This potential difference is then converted into a pH value providing a measurement of how acidic or alkaline (basic) the liquid is. To ensure accuracy calibration plays a role in using pH sensors effectively. Through calibration, sensor readings are adjusted to match known pH standards. Regular calibration becomes necessary as aging or contamination may gradually impact the accuracy of these sensors over time due to changes in their glass membrane. The applications for pH sensors span across industries. In agriculture, they are utilized for monitoring soil pH levels to maintain conditions for plant growth. In industries such as food and beverage production, precise control over pH levels is crucial, for ensuring product quality and safety. Wastewater treatment facilities heavily depend on pH sensors to regulate and optimize the application of chemicals ensuring treatment processes. Figure 3.8, 3.9 depicts the hardware diagram of pH sensor.

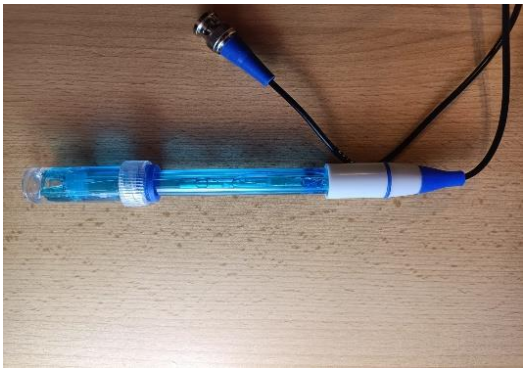

Figure 3.8 pH sensor probe.

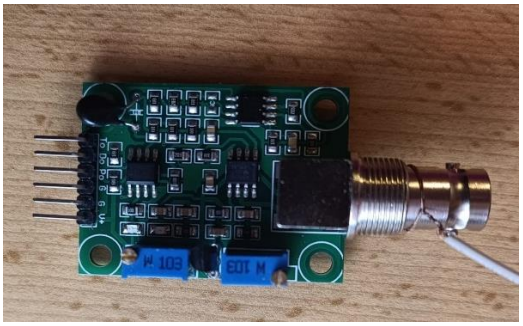

Figure 3.9 pH sensor board.

Ph sensors have a range of applications, in scientific and educational laboratories. Researchers use them to study the acidity levels of solutions in chemical and biological experiments. They also play a role in monitoring the well-being of natural water bodies contributing to assessments. Thanks to advancements digital pH sensors have emerged, offering improved precision, reliability, and user-friendliness. These sensors often come with features like temperature compensation enabling measurements even across varying temperatures. In conclusion, pH sensors are essential tools for measuring the acidity or alkalinity of liquid solutions. Built on principles they provide dependable pH readings, for diverse applications spanning industrial processes to scientific research and environmental monitoring. As technology continues to progress pH sensors will undoubtedly become increasingly crucial in ensuring the quality and safety of products and procedures.

Specification:

- Module power supply: 5 V
- Measuring temperature: 0-50 °C.
- Response time: 1min.
- pH sensor with BNC connector
- Power indicator LED

3.1.7. Submersible pump description

The submersible pump can be fully submersed into the liquid, that is any fluid typically water. In household activities, we use large motor pumps working with the help of electricity to pump water from wells, borewells, and areas where water is below the ground level or the installation point. So, in the prototypes where the same principle is needed, we use miniature submersible pumps that work exactly as the electric pump. The only difference is the use of electricity and the system can be submerged into liquid. Due to efficiency and reliability, they found many applications in industrial areas. The main attractive feature of this pump is its

ability to operate in submersed conditions. Different models of submersible pumps have different capabilities, so it is important to look for the specifications. It should be installed based on the requirement. It needs proper installation and maintenance for proper operation. It helps people to transmit liquid from one location to another. It provides various advantages over traditional electric pumps. Within the waterproofing case, the sealed motor which is the major element of the pump is encased. The major disadvantage of the electrical pumps is the need for frequent priming and cavitation.

The introduction of submersible pumps became the successor of the traditional pump overcoming the limitations of the pumps. The encased motor consists of an impeller and diffuser. The power converts the electrical energy into mechanical energy. Thereby it will create a liquid flow through the impeller and diffuser. It will provide an efficient system. Since it is submersed into the liquid, the operation of the pump creates no noise and also it will reduce the amount of heat produced. These features will help in improving the lifespan of the submersible pump. They have many uses in industries and domestic settings. It also found application in sewage systems, drainage, irrigation, etc... It is also critical for dewatering operations. They can be easily maintained since they are encased into waterproof casing. They can withstand environmental changes. However, periodic inspections and proper installation are essential to ensure optimal performance and longevity. In summary, submersible pumps are reliable and efficient devices that play a crucial role in various applications, from providing a clean water supply to facilitating industrial processes and drainage systems. Their submerged design, energy efficiency, and versatility make them a preferred choice for many pumping needs.

3.1.8 Channel relay description

A relay is, like a switch that uses a magnet to control the flow of electricity between two points. The 8-channel relay module is an electronic component that lets you control multiple electrical devices or circuits all at once. It's designed with eight relays on one board so its convenient and doesn't take up space. People often use this module for lots of things like automation, home automation, robots, and industrial control systems. Each channel in the 8-channel relay module acts as a switch that you can control by itself. This means you can connect eight devices or circuits to the module and have control over each one individually. People usually use this relay module with microcontrollers, like Arduino, Raspberry Pi, or other similar programmable devices so they can include it in projects and systems. You can check out Figure 3.10 for a hardware diagram of the 8-channel relay.

Figure 3.10 8 channel relay.

The 8-channel relay module offers benefits. One of its advantages is its ability to handle voltage and high-current devices making it suitable, for a wide range of applications. Acting as a switch the relay ensures separation between the control circuit (low voltage side) and the load circuit (high voltage side). This separation enhances safety and protects the controlling electronics from damage caused by the connected high-power devices. Typically the relay module operates with a low voltage control signal, 5V or 12V supplied by a microcontroller or other control devices.[16] When the control signal is applied to a channel, that particular relay activates enabling it to switch the high power circuit on or off. This feature makes the 8-channel relay module indispensable in automation scenarios such as managing lighting systems controlling household appliances or overseeing machinery. Additionally, users appreciate its user nature and simple interfaces which usually come equipped with screw terminals, for effortless wire connections and quick setup configuration. The module might also have indicator LEDs, for each channel giving feedback about the state of each relay whether it's open or closed. Overall the 8-channel relay module is a dependable solution for controlling high power devices in various applications. Its small size, isolation capabilities, and easy integration with microcontrollers make it a popular choice, among hobbyists, engineers, and professionals working on automation projects, home automation systems, robotics, or industrial control systems. Whether used in DIY projects or industrial settings the 8-channel relay module offers an efficient way to manage and control loads.

3.2 Software Requirements

The main software components required for the implementation of the system aregiven below:

- Operating system: Windows 8 or above
- IDE Used: Arduino IDE
- Cloud platform: Arduino Cloud

3.2.1 Arduino IDE

The Arduino IDE is a type of software that is freely available for anyone to use and modify. It is designed to help people create and transfer computer code to Arduino boards. For different operating systems, including Windows, Mac OS X, and Linux, the IDE program is appropriate. The programming languages C and C++ are supported. Sketching is a common term for writing a program or piece of code in the Arduino IDE. To upload the sketch created in the Arduino IDE software, we must link the Genuino and Arduino board with the IDE. The drawing has the “ino” file extension.

Users may develop and upload code to a working environment in real-time using the open-source Arduino IDE tool. Since the written code will be sent to the cloud, those that want more redundancy commonly employ it. Any Arduino-based software board is fully compatible with the Arduino IDE. Any operating system, including Linux, Mac, or Windows, may readily implement the program. For smooth compilation and editing, the majority of its components are written in JavaScript. Although the tool’s primary focus is on creating code, it also includes a number of significant functions. For instance, the Arduino IDE enables users to communicate crucial project details with corporate stakeholders. Users have the option to change internal layouts and schematics as necessary. For individuals who want assistance with the installation procedure, comprehensive tutorials are offered. For users with minimal prior experience working with the tool’s framework, tutorials are available. Users give the Arduino IDE top marks for usability. It can carry out complicated operations while using the least amount of computer resources. Users may access their libraries quickly and easily thanks to the tool. The most recent IDE version can assist users with their sketches since it provides updated support for the newest Arduino boards.

Features:

- Open Source: It is an open-source software, that means the users can edit and modify the source code.
- Cross-Platform Compatibility: It can be used in any Operating system.
- Simple Interface: User interface of Arduino IDE is simple, so that even the beginners can easily use the IDE.
- Code Editor: Provide code highlighting, auto-correction, indentation that makes a wonderful coding experience.
- Code Verification: Before uploading the code to the Arduino board, the code can be pre-verified and corrections can be made.
- Serial Monitor: With the help of serial monitor, the data can be viewed in real time and can be debugged and visualized.
- Library Management: It provides built-in libraries that can help the developer in easy coding by importing libraries.

3.2.2 Arduino Cloud

To manage and operate the devices from remote areas, the online services provided by the Arduino is used by developers. These online services that enable the communication between the devices is known as the Arduino Cloud. The manuals and website of Arduino Cloud will provide most recent updates and modifications. To improve the functionality of the project using the Arduino, it provides the users many cloud facilities to analyse and visualise data. It will surely improve the functionality of the system. It will enhance the remote device monitoring and controlling the system. Between the IoT devices and the Arduino devices, the cloud will offer a smooth interaction. It also provides a more configurable dashboard using which users can monitor the firmware changes, safety store and take project data and make statistics based on the real-time. Arduino Cloud have more user friendly interface, by this feature complexity of integrating sensors and actuators is reduced to an extent. It can easily handle many number of Arduino boards making it usable for many applications such as water quality monitoring, home automations, security systems, etc... It can create a new world of innovations.

Features:

- Connect Devices: With the cloud service, it will allow the users to remotely monitor

and control connection between devices. Also, it can connect to different IoT devices.

- Remote Monitoring and Control: Through Arduino cloud platform, users can remotely monitor devices. Services include reading sensor data, observing outputs, performing action based on the devices.
- Data Logging: Data can be stored with ease for further uses and can be analyzed.
- Automation and IoT Integration: Arduino Cloud can be used to create automation rules or integrate Arduino devices into larger Internet of Things (IoT) systems. This allows for more complex and interconnected applications.
- User Interface: Users can interact with their devices through a web-based or mobile user interface provided by Arduino Cloud.

It's important to note that the specific features and capabilities of Arduino Cloud may vary, and new features may have been introduced after my last update. If you have specific questions or need the latest information, I recommend checking the official Arduino website or community forums.

4. IN-DEPTH ANALYSIS OF SYSTEM DESIGN FOR WATER QUALITY MONITORING SYSTEM IN FISH FARMING

4.1 Overview of System Analysis

When a system is proposed, as an initial step requirement analysis needs to be completed. Requirement analysis is an important phase in the development of any system, for providing a structured approach to understand, document, and define the needs and expectations of users. This process involves gathering, documenting, and analysing information about the functions, and constraints of the system. The goal is to create a set of requirements that serve as the foundation for phases of the project lifecycle. Effective requirement analysis requires collaboration with end-users, to ensure that their perspectives and needs are accurately considered. Techniques such as interviews, surveys, and workshops are often employed to elicit and prioritize requirements. The analysis involves refining and organizing gathered information, identifying dependencies, and resolving potential conflicts. Clear and well-defined requirements are essential for guiding the design, development, and testing processes, ultimately contributing to the successful delivery of a system that meets the expectations of its intended users. In the context of Water Quality Monitoring System, the requirements include sensors that can monitor the parameters and the software that can aid in the development of these monitoring system. Here we use sensors like HCSR04 Ultrasonic Distance sensor, DS18B20 Temperature Sensor, TDS Sensor, Turbidity Sensor, pH Sensor. To integrate these sensors and make them work together, we use Arduino IDE. Apart from these parameters, there are many more parameters that determine the quality of the water in the fish pond. But the availability of sensors, limit the measurement of other parameters. To interface each sensor within the system, need to know more about the working of each sensor. HCSR04 Ultrasonic Distance Sensor is used to measure the water level of the pond. Making use of the ultrasonic sound wave, the sensor calculates the water level. It consists of transmitter and receiver. The range of measurement is between 2 cm to 400 cm. Water level of the fish pond depends upon the size of the pond and the type and number of fish in the pond. DS18B20 Temperature Sensor is used to measure the liquid temperature. It is a digital sensor, and is very convenient to use. The sensor have measuring range from -55 degree Celsius to +125 degree Celsius. It is a one wire sensor that is it have one data line to communicate with microcontroller. I ideal temperature

fish pond cannot be determined unless the type of the species is known. Some of the fish needs slightly high temperature and some need cooler water. But in most cases the water can have the temperature range between 25 degrees Celsius and 27 degrees Celsius. Total Dissolved Solids include organic and inorganic substances in suspended form. It can be measured using TDS Sensor. It measures the conductivity of the water and with that it estimates the TDS from that reading. It can measure the value between 0 to 9990 ppm. A level of 400 ppm is recommended for most of the fish ponds. Turbidity is the cloudiness of the water or the clarity of the water. It is caused by the suspended sediments in the water. It is very important to monitor the turbidity of the water. The sensor works on the principle based on the intensity of light transmitted through the water. The measuring range of the turbidity sensor ranges from 0 to 1000 NTU. For a fish pond, almost in all cases, the turbidity needs to be in a range of 50 NTU. pH is the potential of hydrogen that is the amount of hydrogen ions present in the water. Based on the amount of hydrogen ions, water can be alkaline or acidic. The measuring range is in between 0 to 14, where less than 7 indicates acidic nature and above 7 indicates alkaline nature. Ideal pH level of the fish pond is 6.5 to 8.5. It is because this level is close to the pH value of the blood of fish, 7.4. Overall, we cannot define a specified ideal range for each parameter, it depends on the size of the pond and type of the fish cultivated.

The requirement analysis will be completed when the functional requirements analysis and the non-functional requirements analysis are done perfectly. Functional requirements are specifications that define the fundamental capabilities and features a system or product must possess to meet the intended user or business needs. These requirements outline the essential functions, behaviours, and interactions expected from the system, serving as a blueprint for its development. Functional requirements often cover a wide range of aspects, such as user interfaces, data processing, system outputs, and integration with other systems. They are crucial in guiding the design and development process, providing a clear roadmap for developers and stakeholders. Typically documented during the early stages of a project, functional requirements help ensure that the final product aligns with the desired outcomes and meets the specified criteria for functionality, performance, and user experience. Regularly reviewed and refined throughout the project lifecycle, functional requirements play a pivotal role in achieving a successful and effective end product. Non-functional requirements, in the context of software development and system design, are specifications that describe aspects of a system's behaviour and qualities that are not related to its specific functionalities. Unlike

functional requirements that outline what the system should do, non-functional requirements focus on how well the system should perform its functions. These requirements encompass attributes such as performance, reliability, scalability, usability, security, and maintainability. For example, non-functional requirements might specify response times, system availability, or the number of simultaneous users a system should support. Addressing non-functional requirements is crucial for ensuring the overall success and user satisfaction of a system, as they contribute to its efficiency, effectiveness, and overall user experience. Properly defining and managing non-functional requirements during the development process helps guide design decisions, set performance expectations, and ensure that the system meets the broader criteria necessary for its successful operation and acceptance.

4.2. Overview of System Design

In the proposed system, quality of the water will be detected by a turbidity sensor, TDS sensor, pH sensor, and temperature sensor. Automatically powered pumps are also included in this system based on turbidity value and TDS value. The system basically consists of a monitoring module and a pumping module. Two submersible motors have been kept inside the pond which pumps water to the pond that is controlled by a relay. A turbidity sensor is placed in the pond that checks the turbidity of the water. When the turbidity value goes above the maximum value, the submersible pump starts working. These pumps can take water in and out of the pond based on the thresholds of the considered sensor values. The TDS sensor is used to measure the total dissolved solids in the water. The pH sensor and the temperature sensor find the pH value that is the acidity or alkalinity of the water and temperature variation of the water respectively. ESP32 MCU, Turbidity Sensor, TDS Sensor, pH sensor, TemperatureSensor, 8-Channel Relay, and Submersible pump are used to create the suggested system. It has been shown that a water quality monitoring system that integrates IoT is more dependable and effective than a traditional waterquality monitoring system. The development of IoT that works with the ESP 32 Wi-Fi module has made use of the Arduino cloud. This device also allows for real-time water quality monitoring, and automatic motor control.

The analysis of the requirement ends with system description. System description provides the overview of the proposed system's structure, components, and it's working. It also includes the information about the systems related and the technologies. Using the system description, the goals and objectives of the proposed system can be clearly outlined. It is important for the easy understanding of the design, functionality, and capabilities of a

system, and it often serves as a reference for those involved in the development, implementation, and maintenance of the system. It gives details about how the components interact throughout the system and how the data flow through the entire system. With the help of system description, it is easy to see what the system is capable of doing. The proposed system is designed to detect and analyse various chemical and physical parameters of fish ponds to ensure their quality. At the core, it is a hardware infrastructure that contains various components to achieve the purpose. The hardware configuration includes sensors, which are the data collecting modules, that empowers the functionality of the system. These sensors in the hardware setup are used to capture water quality parameters. These may include pH sensors to measure the acidity or alkalinity of the water, turbidity sensors to assess the clarity or cloudiness of the water, TDS sensors to measure the amount of total dissolved solids, temperature sensor to measure the temperature of the water. These sensors are positioned in the fish pond. The data collection modules act as the centre of the system, responsible for collecting, processing, and transmitting the sensor data with the help of ESP32 microcontroller. These systems can provide real-time monitoring. The data collection modules can withstand changes in environmental conditions, thus ensuring proper working of the system. The data collected using these sensors are stored in the cloud and are processed.

With the help of notification, the system alerts the user about the changes that happens in the system. The changes that can takes place is data can go above or below the specified threshold. The hardware prototype of the water quality monitoring system for fish farming is scalable, that means the number of sensors need can be scaled that is cane be integrated to the system easily. The hardware description will provide detailed description about the implementation of the water quality monitoring system. The proposed system is an effective and reliable system that can monitor water quality in real-time. Water quality monitoring system can analyse and report water quality parameters. Sine innovations are on the verge of improvements, water quality monitoring system have wider scope. Hardware components are also evolving that helps in the growth of the fish farming industry. The water quality monitoring system developed using IoT technology strengthens the entire fish farming economy. The system consists of sensors, other connecting devices to form the hardware. It makes use of Arduino IDE and Arduino cloud for data analytics to provide inference about the parameter quality of the water. Thus, it forms an efficient replacement for the traditional water quality monitoring system. The need for the automated water quality monitoring system comes from

the increasing limitations regarding population, environment changes etc... Therefore ensuring proper quality of the water becomes a global priority. IoT aided in the easy integration of water quality monitoring with technology. It allows collection, transmission, and analysis of data from various sensors, so the users can act timely on the quality of the parameters measured using sensors, thereby ensuring the sustainability of water sources. The foundation of the proposed system is sensors which will perform the intended functions. Sensors include pH, turbidity, temperature, total dissolved solids etc...

It uses robust communication protocols for the transmission of data from sensors to cloud. The system can either use MQTT (Message Queuing Telemetry Transport) od CoAP (Constrained Application Protocol) to transfer data. The microcontroller used supports various communication mediums including wireless technologies like Wi-Fi, cellular networks etc...depending on the location and monitoring requirements. The cloud will also support different kind of communication mediums. Through this communication protocols and mediums, the collected data is transferred to cloud services for analysis. Major reason for using cloud services are easy data management and analysis. For the analysis of the trend, data are stored in the cloud. Then long-term analysis is conducted on data retained in the cloud. It can handle data from multiple sensors through these settings. Nowadays many advanced analytical tools are available in cloud services. As a major improvement, machine learning algorithms can also be employed to identify trends in the water quality parameters that helps is early detection of issues. User interface can be developed which helps the users to manage the issues easily through web-based applications or mobile applications.. IoT communication protocols facilitate the transmission of data from sensors to the central server or cloud-based platform. This ensures that information is relayed swiftly and accurately. The collected data undergoes processing and analysis in the central database. Analytics tools examine the data for deviations from established norms, identifying potential water quality issues or anomalies. Upon detecting abnormalities, the system triggers automated alerts and notifications. These alerts can be sent to relevant stakeholders through various channels, including email, SMS, or push notifications on mobile apps. The processed data is presented through a user interface that includes visualization tools. Stakeholders can access comprehensive reports, interactive charts, and maps displaying the current and historical status of water quality parameters. It allows for remote monitoring and control. Stakeholders can access the system from anywhere, facilitating quick decision-making and response to emerging water quality challenges.

There are numerous advantages that increases the popularity of IoT based water quality monitoring system. The IoT-enabled system ensures continuous, real-time monitoring of water quality parameters. This immediacy allows for rapid response to changing conditions and ensures timely interventions. Traditional water quality monitoring methods often involve manual sampling and laboratory analysis, incurring high costs. The automated nature of the IoT system reduces the need for manual intervention, leading to cost savings in the long run. With sensors providing real-time data directly from water sources, the system offers a high level of accuracy. This accuracy is crucial for making informed decisions regarding water resource management. The system's ability to detect anomalies and issue alerts in real time serves as an early warning system. This is invaluable in preventing and mitigating the impact of water contamination events. By providing comprehensive insights into water quality, the system contributes to environmental conservation efforts. Timely identification of pollution sources and effective management practices can help protect ecosystems and biodiversity. The user interface of the system is designed to be accessible to a wide range of stakeholders. This includes water management authorities, environmental agencies, researchers, and even the general public, fostering transparency and community engagement. The modular nature of the IoT system allows for scalability. Additional sensors can be easily integrated into the network to expand monitoring capabilities as needed. The remote monitoring and control features enable authorities to manage water quality from a centralized location. This is particularly beneficial in situations where physical access to monitoring sites is challenging.

4.2.1. Block Diagram

A block diagram is a visual representation that illustrates the structure and interactions within a complex system or process. It is a schematic diagram composed of various interconnected blocks, each representing a distinct component, function, or module of the system. These blocks are typically geometric shapes, such as rectangles or squares, labelled with descriptive text to convey their purpose. Lines or arrows connecting the blocks indicate the flow of information, signals, or energy between them, depicting the system's functional relationships. Figure 4.1 depicts the block diagram of proposed water quality monitoring system. It shows the basic architecture of the system.

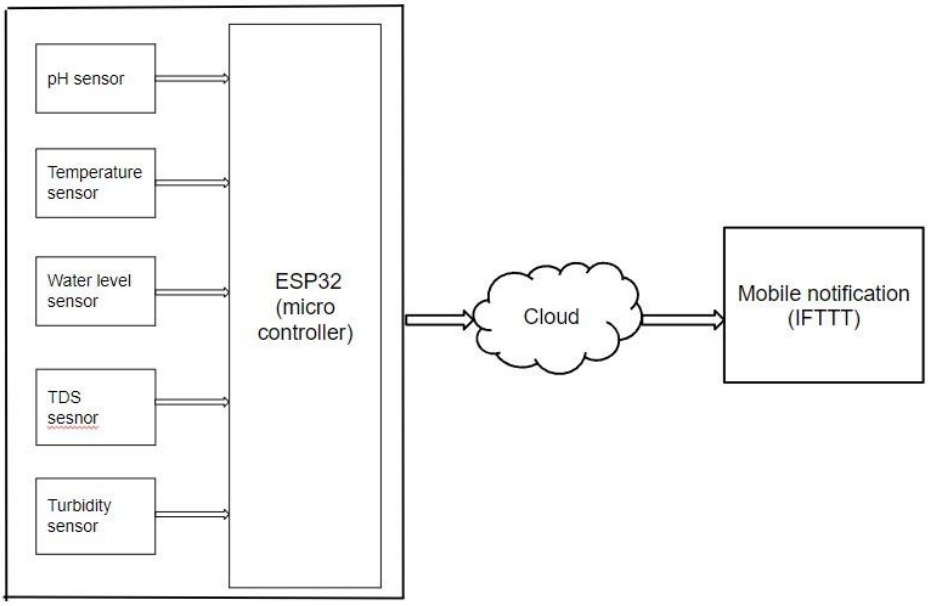

Figure 4.1 Block diagram of proposed Water Quality Monitoring System.

ESP32 Microcontroller

To make the system work, the core component used is the microcontroller. It makes use of ESP32 microcontroller. The ESP32 is a versatile microcontroller and system-on-chip (SoC) that is widely used in IoT (Internet of Things) projects. Developed by Espressif Systems, the ESP32 features a dual-core processor, built-in Wi-Fi and Bluetooth capabilities, ample GPIO (General Purpose Input/Output) pins, and various peripherals. Understanding the pinout is crucial for connecting sensors, actuators, and other peripherals to the ESP32. It offers a powerful platform for building a wide range of IoT applications, from simple projects to complex systems with wireless connectivity. ESP32 have a power supply pin that operates on 3.3 volts. It have a GND pin for the ground reference. It has numerous General Purpose Input/Output pins that can be used as digital input or output. Some GPIO pins can be configured into Pulse Width Modulation output. Analog pins present in the ESP32 acts as the pin for analogue inputs. It also contains pins for I2C communication and SPI communication. I2C stands for Inter-Integrated Circuit. It is integrated into devices for serial communication. SPI is a communication protocol that uses master-slave relationships. It has built-in Wi-Fi and Bluetooth modules with respective pins. For the purposes of programming and debugging, it uses USB pins. The ESP32 microcontroller's pinout refers to the arrangement and functionality of its various pins on the physical device. The ESP32 typically features a range of pins that serve different purposes. Commonly, these pins include GPIO (General Purpose Input/Output)

pins for digital input and output, ADC (Analog-to-Digital Converter) pins for analog sensor readings, UART (Universal Asynchronous Receiver-Transmitter) pins for serial communication, and more. For instance, GPIO pins allow users to interact with digital signals, while ADC pins facilitate analog sensor integration. UART pins enable serial communication with other devices. The ESP32 pinout diagram provides a visual guide, detailing the location and function of each pin, aiding developers in connecting peripherals and sensors for their specific projects. Understanding the ESP32 pinout is crucial for effective hardware interfacing and programming. It can be understood from the Figure 4.2.

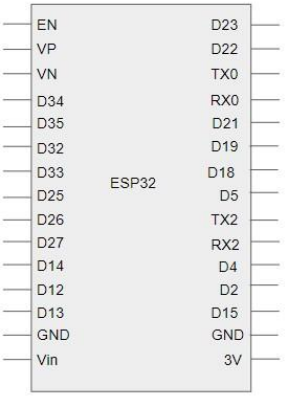

Figure 4.2 Pinout diagram of ESP32 Microcontroller

The proposed water quality monitoring system makes use of five different sensors namely Ultrasonic distance sensor, Temperature sensor, pH sensor, Turbidity sensor, TDS sensor.

HCSR04 Ultrasonic Sensor

The HCSR04 Ultrasonic Sensor is a widely used sensor that can measure distance between objects or detect the presence of the object. The pinout of the HCSR04 Ultrasonic sensor is given in the Figure 4.3. Sensors consists of following pins.

1. VCC (Power): Through this power sensor pin, the sensor receives the operating voltage. It operates at a voltage of 5 Volts. This pin can be connected to the positive pin of the power supply source.
2. Trig (Trigger): Trig pin works for the transmitter. When pulse is sent through the Trig pin, the transmitter will send sound waves and start measuring the distance.
3. Echo: Echo pin works for the receiver. When the object is detected, this pin makes

the receiver available for receiving the sound wave that gets reflected back. The duration of the pulse received on this pin is directly proportional to the distance between the sensor and the object.

4. GND (Ground): GND is the ground or common reference pin, that provides the circuit with common voltage reference. This pin can be connected to the ground terminal of your power supply source.

To use the HCSR04 Ultrasonic Sensor, we need to provide the sensor with power using the VCC and GND. Trig and Echo are used to measure the distance between the objects or detecting the presence of object. These sensors employ waves to accomplish these tasks. A typical sensor setup comprises a transmitter and a receiver. Here's how it works; The transmitter emits a frequency sound wave typically ranging from 20kHz to hundred kHz. The sensor then measures the time it takes for the sound wave to return after striking an object using this delay to calculate the distance between them. If the receiver receives the returning sound wave it confirms the presence of an object. The calculations rely on determining the speed of waves through the medium they travel in.

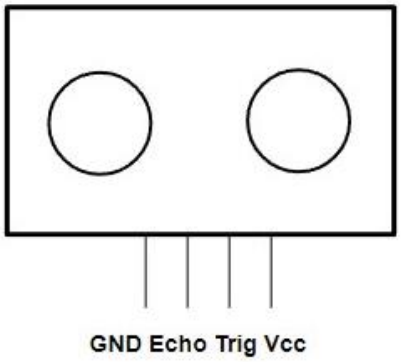

Figure 4.3 Pinout diagram of HCSR04 Distance sensor

DS18B20 Temperature Sensor

The DS18B20 is a digital temperature sensor which can be used to measure the liquid temperature. It will provide accurate and precise output. It is digital sensor consisting of 3 pins. The pinout of the DS18B20 Temperature sensor is explained below:

1. GND (Ground): GND is the ground or common reference pin, that provides the circuit with common voltage reference. This pin can be connected to the ground terminal of your power supply source. It establishes the common ground between

the DS18B20 and the other components in the system.

2. DQ (Data): The communication between sensor and microcontroller is made possible with the help of data pin. Communication protocol utilized by the sensor is one-wire protocol. It allows the connection between microcontroller and multiple temperature sensors. This pin also provides power to the system.
3. VDD (Power): The power supply to the sensor is provided through the VDD pin. It needs an operating range of either 3.0V or 5.5V. This pin can be connected to the positive pin of the power supply source.

Proper wiring of the temperature sensor is vital, otherwise there are many chances to damage of the sensor. To use the DS18B20 Temperature Sensor, we need to provide the sensor with power using the VDD and GND. Data pin is used to make the communication between the sensor and microcontroller happen. The one-wire communication protocol simplifies the integration process, making the DS18B20 a popular choice for temperature sensing in various electronic applications. . With minimal hardware requirements, it provides precise temperature measurements. It is manufactured by Maxim Integrated Products. It can be understood from the Figure 4.4.

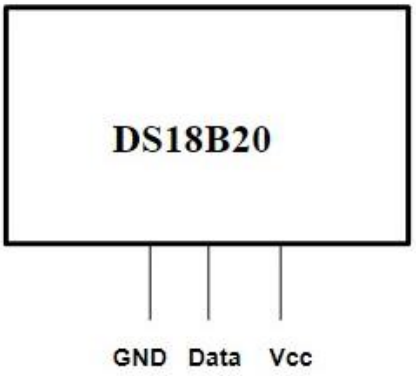

Figure 4.4 Pinout diagram of DS18B20 Temperature sensor.

Potential of hydrogen Sensor

An analog liquid pH sensor are sensors that used to measure the pH level in the liquid. It is mostly used in water quality monitoring systems or hydroponics. It makes use of multiple pins for the operation, Explanation of the pinout of the pH sensor is given below.

1. VCC (Power): Through this power sensor pin, the sensor receives the operating

voltage. It operates at a voltage of 5 Volts. This pin can be connected to the positive pin of the power supply source.

2. GND (Ground): GND is the ground or common reference pin, that provides the circuit with common voltage reference. This pin can be connected to the ground terminal of your power supply source.
3. Analog Output (AO): This particular pin generates a voltage signal that corresponds to the pH level of the liquid being assessed. You simply need to connect this pin to an analog input, on a microcontroller or any other device used for data acquisition.
4. Digital Output (DO): Certain sensors might have a pin, for output which gives a signal (either high or low) determined by a pre set pH threshold. This feature can come in handy to activate actions or raise alarms whenever the pH level surpasses a point.

Temperature Compensation (Temp)

The accuracy of pH readings can be affected by temperature so certain sensors come with a temperature compensation pin. You can connect this pin to a temperature sensor in order to improve the precision of the pH measurements.

When using an analog liquid pH sensor, you typically read the analog output (AO) using an analog-to-digital converter (ADC) on a microcontroller. The obtained analog value can then be converted to a pH reading based on calibration data specific to the sensor. Always refer to the datasheet or documentation provided by the sensor manufacturer for accurate and device-specific information. It can be understood from the Figure 4.5.

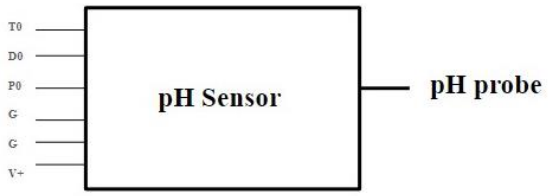

Figure 4.5 Pinout diagram of pH sensor.

Turbidity Sensor

An analog turbidity sensor are sensors that used to measure the cloudiness level in the liquid. It is mostly used in water quality monitoring systems or hydroponics.[17] It makes use of multiple pins for the operation, Explanation of the pinout of the turbidity sensor is given below.

1. VCC (Power): Through this power sensor pin, the sensor receives the operating voltage. It operates at a voltage of 5 Volts. This pin can be connected to the positive pin of the power supply source.
2. GND (Ground): GND is the ground or common reference pin, that provides the circuit with common voltage reference. This pin can be connected to the ground terminal of your power supply source.
3. Signal Output: The output pin of the sensor gives you a signal, either analog or digital that indicates the level of turbidity. You can connect this pin to a microcontroller or another monitoring device to understand and interpret the readings from the sensor.
4. Reference Voltage (optional): Turbidity sensors sometimes come with a pin that allows for a reference voltage. This pin is useful, for establishing a reference point when measuring turbidity levels..
5. Calibration Pins (optional): Some turbidity sensors may include calibration pins that allow for adjusting or calibrating the sensor based on needs. These pins make the calibration process easier. Help ensure readings.

When integrating a turbidity sensor into a project, users typically connect the VCC and GND pins to the power supply, the signal output pin to an analog or digital input on a microcontroller, and any optional pins based on the sensor's specifications. Calibration may be necessary to ensure accurate readings in different environmental conditions or for specific applications. Always refer to the datasheet or documentation provided by the manufacturer for precise details on the pinout and usage of a particular turbidity sensor. It can be understood from the Figure 4.6.

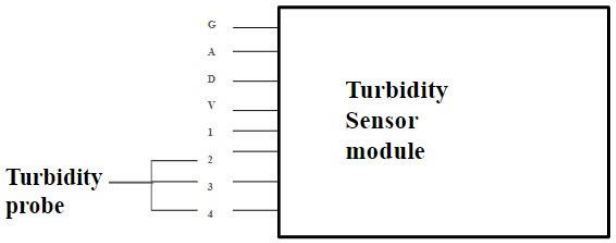

Figure 4.6 Pinout diagram of Turbidity Sensor.

TDS Sensor

A TDS (Total Dissolved Solids) sensor typically features multiple pins that serve specific functions. The exact pinout may vary depending on the sensor model and manufacturer. However, a common TDS sensor pinout often includes the following:

1. VCC (Power): Through this power sensor pin, the sensor receives the operating voltage. It operates at a voltage of 5 Volts. This pin can be connected to the positive pin of the power supply source.
2. GND (Ground): GND is the ground or common reference pin, that provides the circuit with common voltage reference. This pin can be connected to the ground terminal of your power supply source.
3. Analog Output (AO): This particular pin generates a voltage signal that corresponds to the TDS level of the liquid being assessed. You simply need to connect this pin to an analog input, on a microcontroller or any other device used for data acquisition.
4. Digital Output (DO): Certain sensors might have a pin, for output which gives a signal (either high or low) determined by a pre set TDS threshold. This feature can come in handy to activate actions or raise alarms whenever the TDS level surpasses a point.
5. Temperature Sensor: Some TDS sensors may also include a temperature sensor, often denoted by a "Temp" or "Temperature" pin. This pin outputs a signal proportional to the temperature of the water being measured.

TDS Sensor measures the total dissolved solids in the given sample. It is used in aquariums, swimming pools and other hydro systems. TDS Sensor is measured by monitoring

the conductivity of the liquid. This is correlates with the concentration of dissolved solids. Two electrodes are present in the sensor. It is then immersed into the sample liquid. Through one electrode, electric current is applied and then the conductivity is measured by the other. It can be understood from the Figure 4.7.

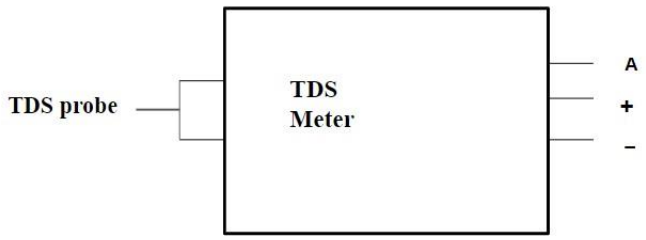

Figure 4.7 Pinout diagram of TDS Sensor.

4.2.2. Communication Protocols

The selection of the communication protocol, between a microcontroller and the cloud relies on factors, including the requirements of the application, bandwidth availability, power consumption considerations and the specific cloud service being utilized. There are used protocols for facilitating communication between microcontrollers and the cloud.

1. MQTT (Message Queuing Telemetry Transport): MQTT is a lightweight and efficient messaging protocol that is widely used in IoT (Internet of Things) applications. It is particularly suitable for scenarios where low bandwidth usage and minimal power consumption are essential. In this protocol devices can publish messages to a broker, which then distributes them to subscribing devices.
2. HTTP/HTTPS (Hypertext Transfer Protocol/Secure): These protocols, commonly employed for web communication can also be used for microcontroller to cloud communication. Devices can make HTTP requests to servers using APIs (Application Programming Interfaces). The addition of HTTPS ensures data encryption and security making it appropriate for applications that require data confidentiality.
3. CoAP (Constrained Application Protocol): CoAP is specifically designed for devices with resources and networks found in IoT applications. It is a protocol that functions effectively, in resource constrained environments typically associated

with microcontroller-based applications.

4. WebSocket: WebSocket offers a communication channel that allows bidirectional data exchange, through a long-lasting connection. This is particularly useful for applications that necessitate real time communication between the microcontroller and the cloud. Employing WebSocket's enables the establishment of a connection to facilitate reliable messaging.

One alternative protocol, AMQP (Message Queuing Protocol) supports communication among components of a distributed system. With its focus on efficiency and reliability AMQP is well suited for scenarios where dependable message delivery's essential. The selection of a protocol depends on factors such, as application requirements, microcontroller capabilities and the features provided by the chosen cloud platform or service. It's common for devices to utilize a combination of these protocols to address different communication needs within their system architecture.

4.2.3. Circuit Diagram

The proposed system consists of ESP32, an Ultrasonic sensor, a Turbidity sensor, a TDS sensor, a Temperature sensor, a pH sensor and a submersible pump controlled by an 8-channel relay, and a Power Supply to power the module. The ultrasonic sensor and the temperature sensor are digital sensors that make use of the digital data input pins of the ESP32 while the turbidity sensor, pH sensor and the TDS sensor are analog sensors that use the analog data input pins. The submersible pumps make use of the output data pins of ESP32. Figure 4.8 refers to the circuit diagram of the proposed water quality monitoring system. In the pin out of the ESP32, GND and Vin are power supply pins. Each positive and negative pins of sensors are connected to the Vin and GND pins respectively. From the Figure 4.8, it is evident that TDS sensor, pH sensor and Turbidity sensor uses analog pins say D35, D34, VP respectively. Ultrasonic distance sensor utilizes D18 and D5 as the echo pin and trig pin. Temperature sensor makes use of D2 pin.

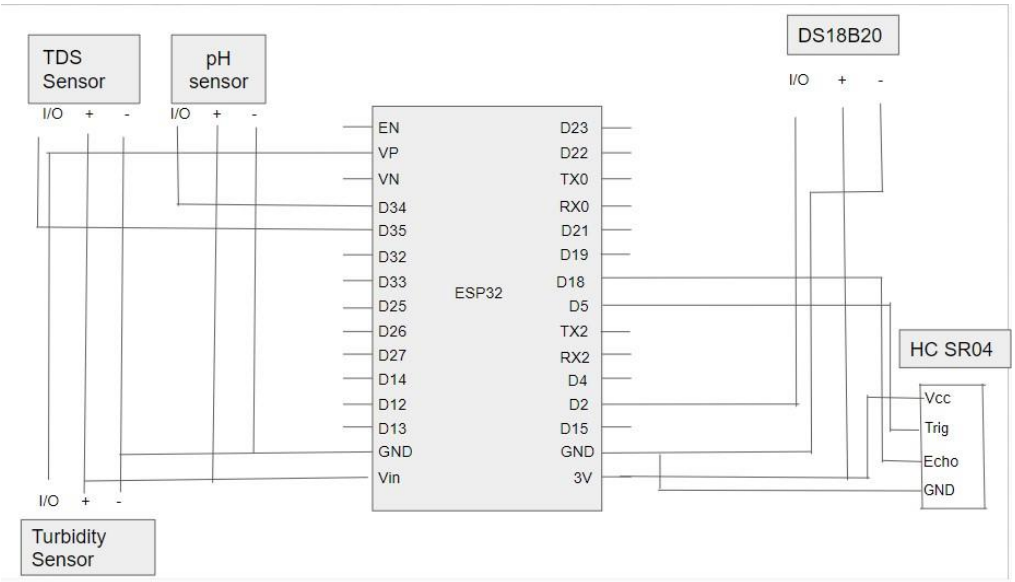

Figure 4.8 Circuit Diagram of Proposed Water Quality Monitoring System.

4.2.4. Flowchart

Flowchart represents the flow of data throughout the system. It is the pictorial representation of the algorithms that gives the step-by-step approach to solve the problem. Figure 4.9 depicts the flowchart of the proposed water quality monitoring system. When the system starts ESP32 Microcontroller is initialized with the help of the external power supply. The microcontroller has been loaded with the code required for the working of the system. The values of the parameters are measured using sensors depending on the requirements. These values are then uploaded into the IoT Cloud. IoT Cloud can be used for the further analysis and visualisation processes. If the value of parameter is greater than or lesser than the threshold set by the particular user, notifications are sent to users and based on this notification, farmers need to take necessary actions. Else the system continues to monitor the water quality of the fish farm. The flowchart helps to understand the processes and work flow of the system.

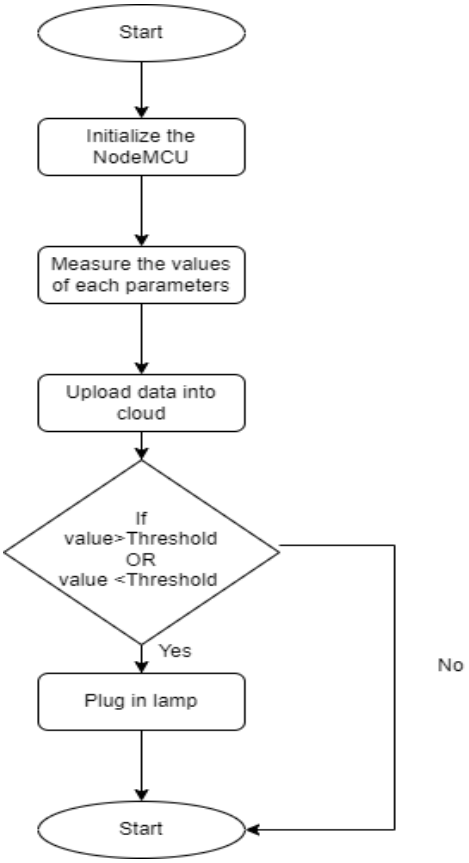

Figure 4.9 Flowchart depicting work flow of the System.

5. IMPLEMENTATION AND RESULTS

Fish farming plays a role, in the food industry as it provides a sustainable source of protein. However, maintaining optimal water quality is crucial for the well-being and growth of organisms. To tackle this challenge, it becomes necessary to establish a water quality monitoring system. This involves integrating sensors, microcontrollers, and cloud-based technologies to continuously assess and manage water parameters. In this step-by-step process of implementing a water quality monitoring system for fish farming three main components are involved; sensors for data collection, a microcontroller for data processing, and cloud connectivity for real-time monitoring and analysis. Various sensors are utilized to measure water parameters such as temperature, pH levels dissolved oxygen (DO) ammonia, nitrate, and turbidity. Each sensor is strategically positioned within the fish farm to ensure data collection. Acting as the brain of the system a microcontroller like Arduino or Raspberry Pi collects data from these sensors processes it accordingly and transmits it to the cloud. Cloud-based platforms are employed for data storage purposes along, with analytics capabilities and remote access.

The information sent from the microcontroller is securely saved in the cloud enabling farmers to use apps and monitor water quality in time. It's crucial to place sensors within the fish farm, for data gathering. Equally important is calibrating these sensors to ensure readings. This involves adjusting them to known standards and verifying their accuracy against reference measurements. Regular calibration checks are done to maintain the accuracy of the monitoring system.

Selecting the sensors is vital for water quality monitoring. Different parameters require sensors. For instance, monitoring water temperature is crucial as it affects fish's metabolic rate. It ensures that the water temperature stays within a range for fish species. Measuring acidity or alkalinity determines the pH level of water which greatly impacts fish health and biological processes in environments. Assessing water clarity caused by suspended particles is also critical for visibility. Ensuring conditions for fish. Many other parameters are frequently measured to ensure water quality. The microcontroller is programmed to collect data, from the sensors at intervals using data processing algorithms and communication protocols.

For instance, if the level of dissolved oxygen drops, below a threshold the microcontroller can activate sensors to alert and activate mechanisms that aerate the water. The microcontroller can store data locally. Send it to a cloud platform for monitoring and analysis over time. Integrating with the cloud involves configuring the microcontroller to communicate

with the chosen cloud platform. Once connected real-time data can be transmitted from the microcontroller to the cloud, where it is stored and accessible through a user interface. Cloud platforms also provide features like setting up alerts, notifications, and tools for analysing data, which offer insights for managing farms effectively. Having a system in place is crucial for responding to changes in water quality.

By using predetermined thresholds this system can send email or SMS notifications, to either the fish farmer or designated personnel. This allows intervention to address any issues and protect fish health from adverse effects. One of the advantages of a water quality monitoring system connected to the cloud is its ability to monitor and control fish farms remotely. Farmers can access real-time data on their smartphones or computers. Receive alerts when necessary. Remote monitoring enables decision-making. Empower farmers to respond swiftly as conditions change. Cloud platforms also offer robust analytics tools for processing and visually representing data.[11]

Analysing data helps us identify trends, correlations, and areas where we can make improvements. Reports and dashboards give us a picture of water quality parameters over time, which helps with decision-making and long-term farm management strategies. To enhance the water quality system, we can integrate actuators for control. For example, if the ammonia level goes beyond a limit the system can automatically trigger a water exchange. Activate aeration systems to address the problem. By automating these processes, we reduce the need, for intervention. Ensure quick responses to changing conditions. It's crucial to implement security measures to protect the data collected by our water quality monitoring system. We use encryption protocols, secure connections, and access controls to keep information safe. Regular security audits and updates are conducted to address any vulnerabilities. Integrating our water quality monitoring system with farm management systems is also beneficial for operations on the farm. This integration allows coordination with feeding schedules, production planning, and other aspects of aquaculture management. The data from our water quality system plays a role in making rounded decisions for optimizing overall farm performance.

In this project, we have set threshold values for each parameter as a convenience for developers. However, it's important to note that these thresholds may need adjustments, in the future. The variation, in fish cultivation practices, is specific, to each species. Users can define this variation based on the fish species they are raising. The threshold values used in this proposed system are shown in the Table 5.1.

Table 5.1

List of critical parameters and their threshold

PARAMETER	THRESHOLD
Temperature	22-30 °C
pH	6.5-8
Turbidity	30 NTU
TDS	1000 ppm

Implementing a water quality monitoring system, for fish farming is a yet straightforward process that involves planning deploying sensors, programming microcontrollers integrating with the cloud, and ongoing maintenance. Such a system offers real time insights into water parameters for fish farmers enabling management and sustainable aquaculture practices. With advancing technology, the integration of monitoring and automation systems becomes increasingly essential in the aquaculture industry to meet growing demands while ensuring the well-being of aquatic life and environmental sustainability.

Setting thresholds for water quality parameters is vital in fish farming to ensure the health and well-being of organisms. Different fish species have varying tolerances to conditions; hence it is crucial to customize the thresholds based on each fish type's requirements. The system should allow flexibility in customizing and adjusting threshold values to accommodate variations in conditions for types of fish. It should be adaptable to meet the needs of fish species considering factors, like temperature preferences, pH tolerances, and oxygen requirements. Assess the system's ability to adapt monitoring thresholds and recommendations based on the requirements of fish species, in the same aquaculture facility.

There is a pond and a water source that supplies water to the pond. Inside the pond, there are four sensors placed; a temperature sensor, a water level sensor, a TDS (Total Dissolved Solids) sensor, and a turbidity sensor. These sensors monitor the quality of water parameters. Alongside these sensors, the proposed system also includes two pumps that assist in water intake and outflow controlled by single-channel relays. In this proposed system various sensors are integrated into an ESP32 microcontroller. Distance sensors, temperature sensors, turbidity

sensors, TDS sensors, and pH sensors utilize data pins within the ESP32 microcontroller. The water level distance sensor uses data pins 18 and 19 as its echo pin and trig pin respectively. Similarly, the temperature sensor, turbidity sensor, TDS sensor, and pH sensor use data pins 17 34 35, and 32 respectively.

5.1. Results

A water quality monitoring system for different species of fish is a critical component of modern aquaculture practices. The analysis should focus on the system's ability to provide accurate, real-time data, adapt to the specific needs of diverse fish species, and offer features that contribute to the overall health and sustainability of the aquaculture operation. Regular updates, support, and flexibility in system configuration are essential for ensuring the long-term success of the water quality monitoring system in diverse fish farming scenarios. The table below shows the average thresholds for four different types of fish. It focuses on Tilapia, Trout, Catfish and Salmon. Analysing the data, we can understand that Tilapia can cope with slightly higher temperatures while Salmon needs cooler water. Since the pH value of blood of fish is 7.4, pH value of the pond water should approximate with 7.4. The turbidity value should not go above a value greater than 50 NTU. While talking about the TDS, most of the fish can cope with the value of 1000 ppm while trout can only deal with value of 500 ppm. The threshold depends on the type of fish under cultivation. In this project, we use different types of water samples, and are tested with the developed Water Quality Monitoring System. Table 5.2 presents the critical parameters and their threshold values for different species of fish that are used in the project.

Table 5.2

Critical parameters and their threshold for different species of fish

TYPE OF FISH	TEMPERATURE (°C)	pH	TURBIDITY (NTU)	TDS (ppm)
Tilapia	25-30	6.5-9.0	<50	300-1,000
Trout	10-20	6.5-8.0	<10	150-500
Catfish	25-30	6.5-8.5	<50	300-1,000
Salmon	10-14	6.0-8.0	<10	300-1,000

5.1.1. Clear Water

Using the developed system, a sample of clear water is collected and is tested. The result of the test visualized in the Arduino Cloud is shown below. Since the pond is full, water level is shown as 100 percent. Total Dissolved Solids in the clear water is 170 ppm. The temperature value of the clear water is 26.8 degree Celsius. The clarity of the water is 7.82 NTU. pH of the clear water is 7.3, that is it is neutral. Whenever the value goes above or below the fixed threshold, the system will automatically send the notification. With the help of this notification, users can take necessary actions. The value of the parameters for specified time interval is also shown below. By analysing the results of clear water, we get to know that the water can be used for cultivating Trout.

Figure 5.1, 5.2 Sample of clear water for testing.

Figure 5.3 Visualisation of parameter values in clear water in PC.

Figure 5.4 Visualisation of parameter values in clear water in mobile phone.

Temperature=26.80
Turbidity=7.82
TDS=170.00
distance=100
Ph value=7.30
Temperature=26.80
Turbidity=7.82
TDS=170.00
distance=100
Ph value=7.30
Temperature=26.80
Turbidity=7.82
TDS=170.00
distance=100
Ph value=7.30

Figure 5.5 Parameter values in clear water.

5.1.2. Alkaline Water

Using the developed system, a sample of alkaline water is created by adding baking soda in water and tested. The result of the test visualized in the Arduino Cloud is shown below. Since the pond is full, water level is shown as 100 percent. Total Dissolved Solids in the clear water is 175 ppm. The temperature value of the clear water is 25.5 degree Celsius. The clarity of the water is 6.92 NTU. pH of the clear water is 10. The alkaline water is basic in nature having pH value greater than 7. Since the pH value of the given sample is 10 and is greater than

the threshold for pH level for growing fish, this alkaline water cannot used for cultivating fish. Whenever the value goes above or below the fixed threshold, the system will automatically send the notification. With the help of this notification, users can take necessary actions. The value of the parameters for specified time interval is also shown below.

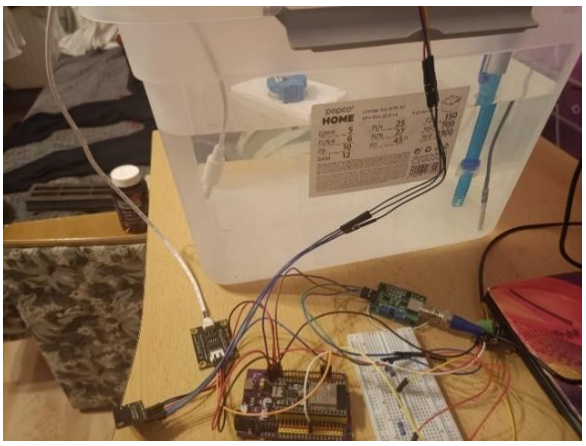

Figure 5.6 Sample of alkaline water for testing.

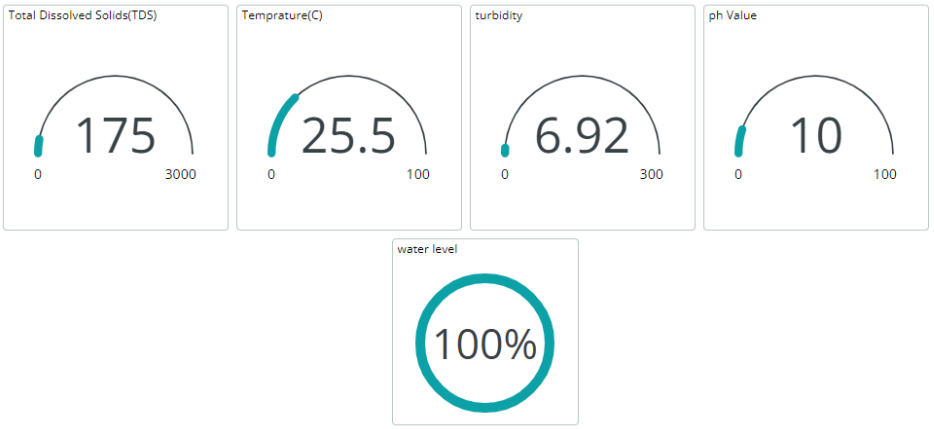

Figure 5.7 Visualisation of parameter values in alkaline water in PC.

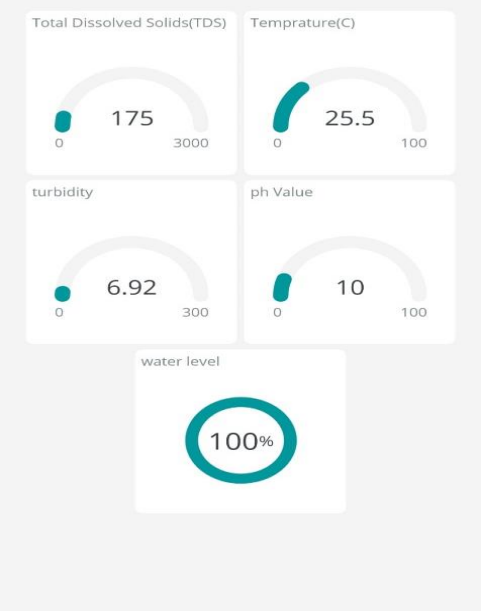

Figure 5.8 Visualisation of parameter values in alkaline water in mobile phone.

```
Temperature=25.50
Turbidity=6.92
TDS=175.00
distance=100
Ph value=10.00
Temperature=25.50
Turbidity=6.92
TDS=175.00
distance=100
Ph value=10.00
Temperature=25.50
Turbidity=6.92
TDS=175.00
distance=100
Ph value=10.00
Temperature=25.50
```

Figure 5.9 Parameter values in alkaline water.

5.1.3. Acidic Water

Using the developed system, a sample of acidic water is collected and tested. The result of the test visualized in the Arduino Cloud is shown below. Since the pond is full with the threshold set by the user, water level is shown as 100 percent. Total Dissolved Solids in the clear water is 172 ppm. The temperature value of the clear water is 25.5 degree Celsius. The clarity of the water is 6.62 NTU. pH of the clear water is 3. The given water sample is acidic in

nature having pH value less than 7. Since the pH value of the given sample is 3 and is lesser than the threshold for pH level for growing fish, this acidic water cannot used for cultivating fish. Whenever the value goes above or below the fixed threshold, the system will automatically send the notification. With the help of this notification, users can take necessary actions. The value of the parameters for specified time interval is also shown below.

Figure 5.10 Visualisation of parameter values in acidic water in PC

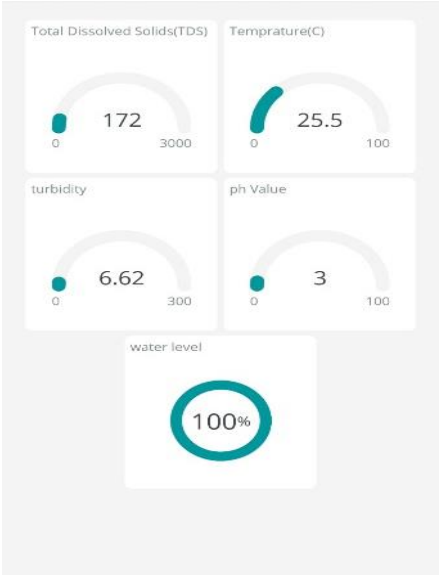

Figure 5.11 Visualisation of parameter values in alkaline water in mobile phone.

Temperature=25.50
Turbidity=6.62
TDS=172.00
distance=100
Ph value=3.00
Temperature=25.50
Turbidity=6.62
TDS=172.00
distance=100
Ph value=3.00
Temperature=25.50
Turbidity=6.62
TDS=172.00
distance=100
Ph value=3.00
Temperature=25.50

Figure 5.12 Parameter values in alkaline water.

5.1.4. High temperature water

Using the developed system, a sample of high temperature water is created and tested. The result of the test visualized in the Arduino Cloud is shown below. Since the pond is full, water level is shown as 100 percent. Total Dissolved Solids in the clear water is 175 ppm. The temperature value of the clear water is 40 degree Celsius. The clarity of the water is 9 NTU. pH of the clear water is 7.6. Whenever the value goes above or below the fixed threshold, the system will automatically send the notification. With the help of this notification, users can take necessary actions. The value of the parameters for specified time interval is also shown below.

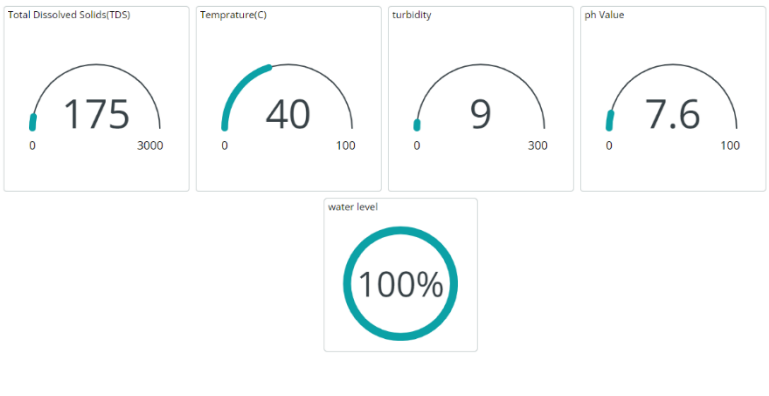

Figure 5.13 Visualisation of parameter values in high temperature water in PC.

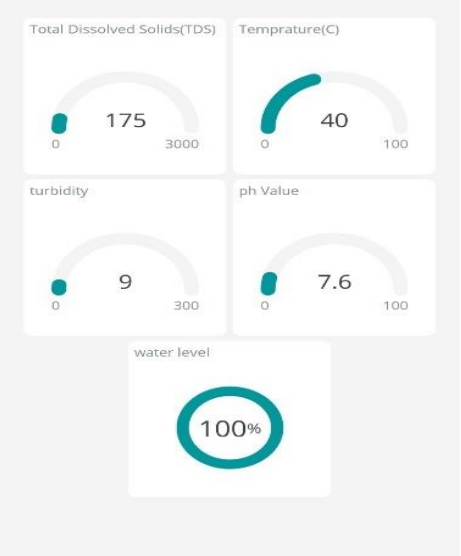

Figure 5.14 Visualisation of parameter values in high temperature water in mobile phone.

Temperature=40.00
Turbidity=9.00
TDS=175.00
distance=100
Ph value=7.60
Temperature=40.00
Turbidity=9.00
TDS=175.00
distance=100
Ph value=7.60
Temperature=40.00
Turbidity=9.00
TDS=175.00
distance=100
Ph value=7.60
Temperature=40.00

Figure 5.15 Parameter values in high temperature water.

5.1.5. Dirty water

Using the developed system, a sample of cloudy water is created and tested. The result of the test visualized in the Arduino Cloud is shown below. Since the pond is full, water level is shown as 100 percent. Total Dissolved Solids in the clear water is 1475 ppm. The temperature value of the clear water is 28.5 degree Celsius. The clarity of the water is 39 NTU. pH of the clear water is 7.6. Whenever the value goes above or below the fixed threshold, the system will automatically send the notification. With the help of this notification, users can take necessary actions. The value of the parameters for specified time interval is also shown below.

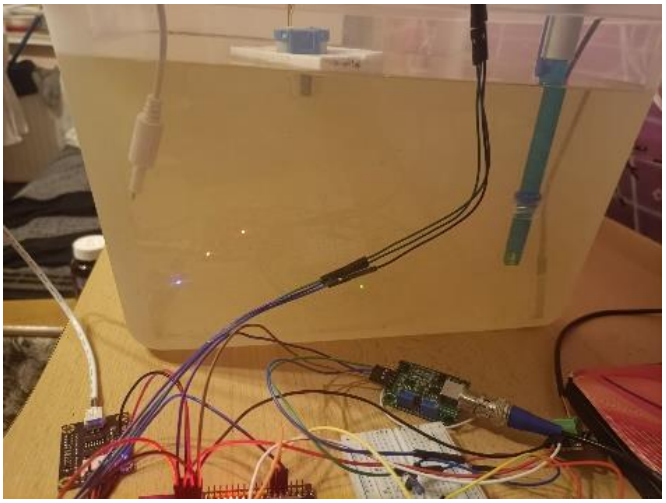

Figure 5.16 Sample of dirty water for testing.

Figure 5.17 Visualisation of parameter values in dirty water in PC

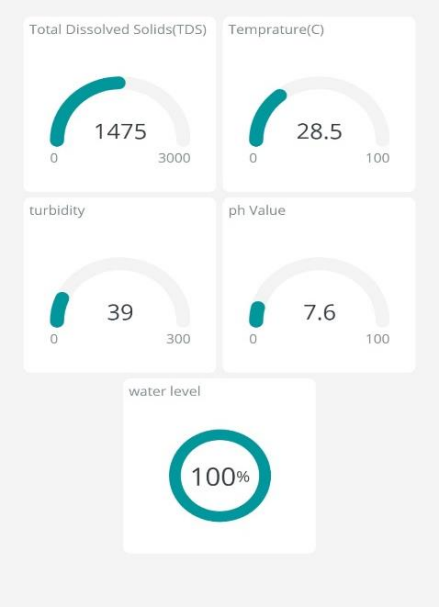

Figure 5.18 Visualisation of parameter values in dirty water in mobile phone.

Temperature=28.50
Turbidity=39.00
TDS=1475.00
distance=100
Ph value=7.60
Temperature=28.50
Turbidity=39.00
TDS=1475.00
distance=100
Ph value=7.60
Temperature=28.50
Turbidity=39.00
TDS=1475.00
distance=100
Ph value=7.60
Temperature=28.50

Figure 5.19 Parameter values in high temperature water.

Table 5.3

Test Result of different type of water in the system

TEST WATER	TEMPERATURE (°C)	pH	TURBIDITY (NTU)	TDS (ppm)
Clear Water	26.8	7.3	7.82	170
Alkaline Water	25.5	10	6.92	175
Acidic Water	25.5	3	6.62	172
High Temperature Water	40	7.6	9	175
Dirty Water	28.5	7.6	39	1475

The above table 5.3 gives the test results of various expriment that we done.It is important to analyse the results for the better understanding of the system. This will make us to know which water is suitable for fish farming. From the analysis of above results we get to know that not all water is safe for fish cultivation. It keeps on changing based on the type of the fish. Level of water in the fish pond depends on the size of the pond and amount fish seeds present. TDS and Turbidity helps farmers to know about the contamination level of the water. The water should be always neutral in nature, else the growth of the fish is retarded affecting the economic growth. When this parameter values have higher variations, action are required for the better growth of the fish.

6. CONCLUSION

The proposed water quality monitoring system for fish farm utilizes IoT technology and cloud services for the development and implementation. The aim of the system is monitoring the water parameter quality efficiently. Initially, literature review is conducted and current trends in quality monitoring is identified. With the help of literature review, a study on existing study is completed and there are numerous limitations for the existing water quality monitoring system. To overcome these limitations, a new system is proposed.

After analysing the critical parameters, we concluded to monitor the parameters like TDS, Turbidity, Temperature, pH and water level. A feasibility study conducted to get to know about the affordability of the sensors required. Sensors such as temperature sensors, TDS sensors, turbidity sensors, pH sensors and distance sensors are used to monitor the quality of the water in fish farm. The system is a cost-effective approach to monitor water quality. It makes use of cloud services. The sensors collect data using ESP32 Microcontroller. Both physical and chemical parameters are monitored using this system. The gathered parameter values are fed to the Arduino Cloud for analysis and visualisation.

Many peripheral equipment and sensors are used for the efficient and reliable system. This proposed system find its application in households and water purification plants. Without high cost, the system can be setup and can be integrated into the pond. It is very much important for solving major challenges faced by the fish pond.

This IoT-based system for monitoring water quality proves reliable and efficient when assessing parameters within the water. The development process of this system can be accomplished with ease. Parameters such as temperature, turbidity, total dissolved solids, water level, and pH level among others are monitored by this system. It is especially suitable for ponds measuring, around 500 feet in size. Minimal human intervention is required for the proposed system. So, the main advantages of this technology include reducing the need, for labor lowering costs, and saving energy. Regular maintenance is necessary as the sensors used are quite sensitive.

7. FUTURE ENHANCEMENTS

In the proposed system, based on the availability of the sensors in the market and depending on the feasibility, temperature, pH, water level, TDS, and turbidity are measured. For measuring these parameter values, particular sensors are available. Here, temperature, pH, and water level are the most vital parameters that need to be monitored frequently. Measuring TDS and turbidity helped in understanding the Dissolved oxygen content in the water. Using the above parameters, the quality of the water source can be effectively measured. The automated water quality monitoring sensors enhance the pond quality. To enhance the system further, more advanced sensors can be added to make it reliable and accurate. Dissolved oxygen is a vital parameter that ensures the quality growth of the water. Adding a DO sensor can improve the functionality of the system. Since the system is dealing with fish, we can also add a feeding system into the prototype. Without a feeder system, the farmer needs to supply feed in regular interval and this process needs human labor. By adding a feeder system, this process can be automated. Thus, it improves the usability and functionality of the system. A system that operates without internet connection can make the system more practical for areas with limited connectivity.

A recycling system that filters the turbid water and reuse it into the pond can save a lot of water. This is very useful in areas there is scarcity in water. These features can enhance the system's performance, efficiency and reliability. Together with this hardware features, there are many software features that can be added to enhance the system further. A better user interface can make the work of the farmers much easier. Through a mobile application or a web application, the fluctuations in the parameter values can be viewed easily. Alert notifications can be send using these interfaces. Robust cybersecurity measures can be implemented to preserve the integrity and confidentiality of the data. It is necessary to prevent unauthorized data access. To the existing system, we can integrate Artificial Intelligence and Machine Learning algorithms for more sophisticated data analysis and early detection of water quality anomalies. Thus, by these future enhancements, the system can be more reliable and sustainable.

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