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Intelligent Irrigation System Using IoT for Aquaponics Application

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Abstract: Nowadays, everything in our daily life applying technology. Internet of Thing (IoT) is one of the modern technologies where we can monitor and control something from distance through internet. In this case, IoT are applied on the aquaponics application to fully monitor the water quality for the plant and fish to thrive. This research intends to automate the construct of an IoT-based prototype to monitor and gather parameter data in the Aquaponics ecology, including water level, humidity level, and temperature, thereby integrating the IoT Framework into Aquaponics. The method that are used is applying a few sensors that are TDS, temperature and pH and connect it to Node MCU esp8266 that act as a controller and send data to the Blynk application. As a result, the fish and plant can grow healthily because the quality of the water are being monitored through IoT application. In general, this research can save a lot of time and effort for farmer and hobbyist to operate the aquaponic system

Keywords: Aquaponics, Monitoring, IoT, TDS, pH. Temperature, Node MCU

1. What is Aquaponics?

Aquaponics system is a combination of Aquaculture that is the cultivation of aquatic organisms in controlled aquatic environments for any commercial and hydroponics is simply the growing of plants without soil.[1] Aquaponics is the study of how water, marine species, bacteria, nutrient dynamics, and plants interact in waterways around the world. Taking inspiration from nature, aquaponics leverages the power of bio-integration to transform the fish waste by-product into a fuel for bacteria, converting it into the proper fertilizer for the plants, and returning the water to the fish in a clean and healthy manner. In an aquaponics system, fish are kept on tanks, and their waste is pumped to vegetables grown in gravel-filled grow beds. The nitrates are taken up by the roots, which then grow rapidly.[2] The water is purified and returned to the tank. The organic veggies and fish give a well-rounded diet, which is beneficial in today's uncertain world

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Nutritionally, food grown in an aquaponic garden is healthier, fresher, and genuinely organic because plants and fish are not contaminated with pesticides or weed killersaqua[3]. IoT can be applied with IoT application. The IoT based Aquaponics Monitoring system features to monitor pH value, temperature, EC value and TDS value using the specific sensors has been done and then after perceiving those values from the sensors and supplied it to the controller and to the IoT application.

2. The Design Methodology and Construction of Aquaponics

This system can be divided into several parts which are input, controller, and output. In the input part consists of four sensors which are water flow sensor, temperature sensor, pH sensor and TDS sensor. The block diagram had been displayed in Figure 1.

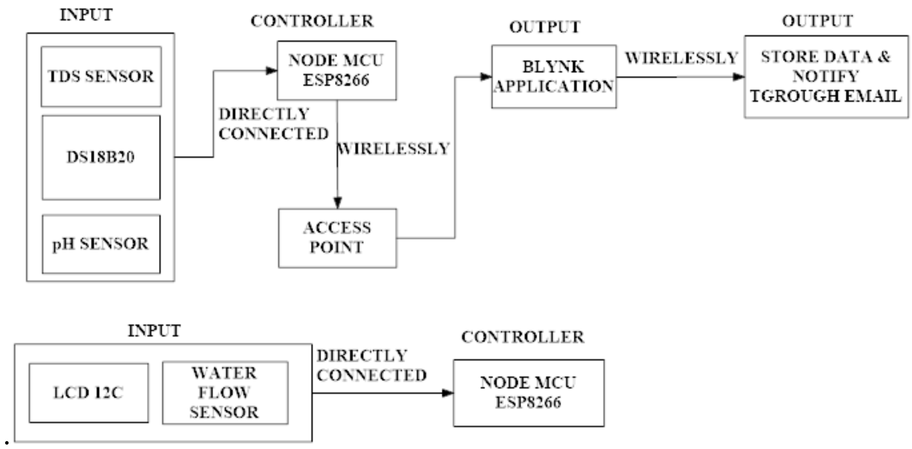

Figure 1: The block diagram of the project system

2.1 Flowchart

The flowchart of the system is started with reading the input data that are temperature, TDS level, EC value, and water flow from its own sensor. Next, after the input data are obtained, it will be directly sent to the Blynk application of its users, and the values will display on their smartphone's Blynk application. If the pH level, temperature, TDS level and EC value exceed or less than the threshold value the microcontroller will act as an actuator to send notification to the smartphone's Blynk application and send email to the user. TDS or total dissolved solid is to monitor the quality of the water while EC or electric conductance is to indicates the strength of nutrient concentrations for plants and animals. Temperature sensor is used to measure the temperature of the water whether it exceed the threshold value or not. pH sensor is to determine the acidity or alkalinity of water. The flowchart had been constructed as in Figure 2.

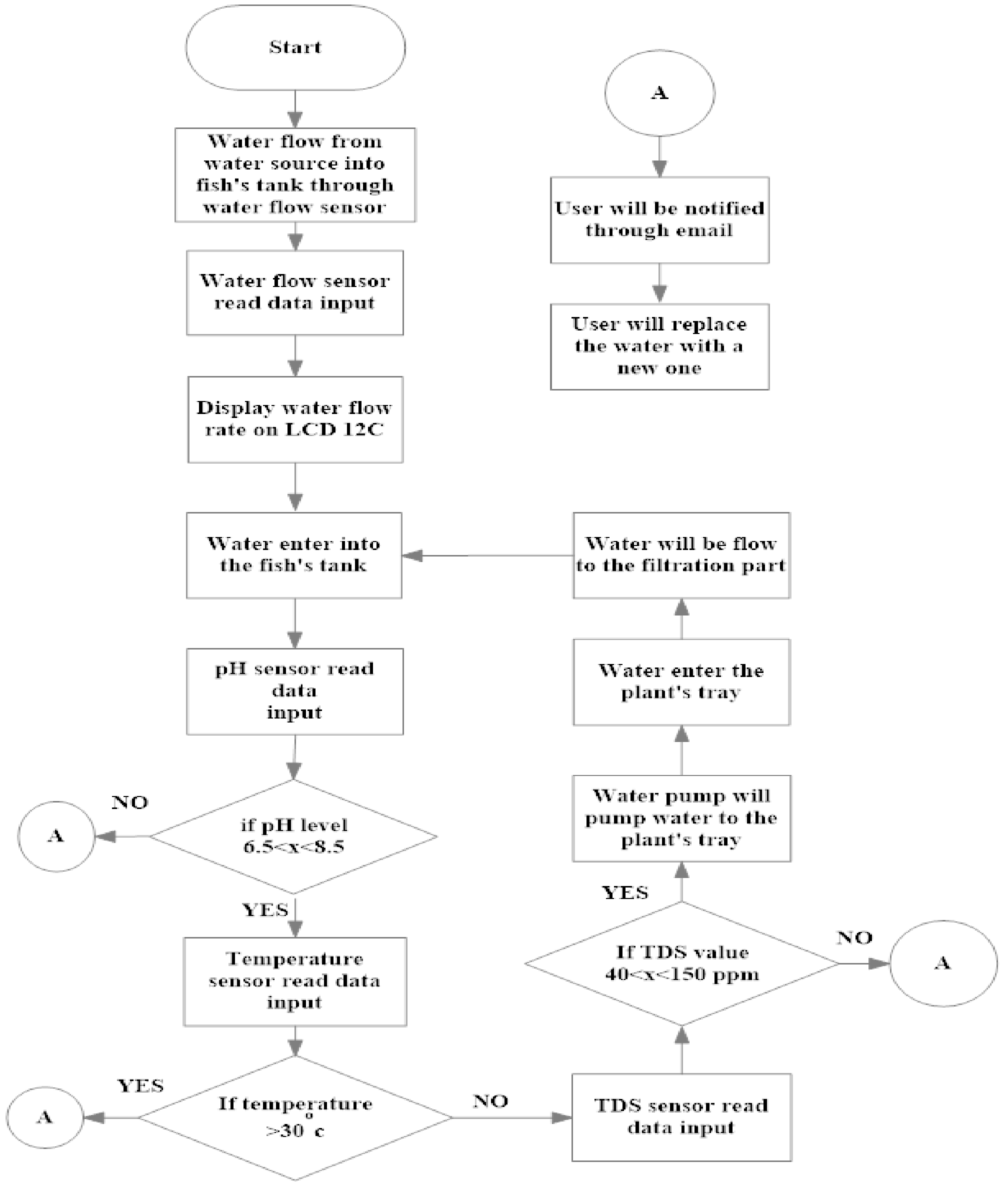

Figure 3: Flowchart of the system

2.2 Hardware setup

The Microcontroller was equipped with two sensors as shown in Figure 4, one for monitoring TDS levels and the other, a temperature sensor DS18B20, for measuring temperature. All sensors were connected directly to their respective voltage input pins and GND pins to allow for circuit circulation, with the input wire additionally attached to their corresponding digital pins to allow for sensor communication. A 4.7 k resistor was also placed between the Vin and the data input of the DS18B20 circuit to prevent overvoltage.

To make room for a mechanical component to be added to this project. In this part of the project, a water flow sensor, and an LCD 12C were employed. Both the sensor and the LCD 12C were linked to the microcontroller through pins, allowing communication between the sensor and the data to be monitored as shown in Figure 4

The pH level sensor is also connected to the third microcontroller as shown in Figure 4, bringing the total number of microcontrollers to three. It was chosen not to combine the microcontroller with the microprocessor, which already included a TDS and a temperature sensor, to avoid overvoltage to the microcontroller. Instead, the voltage pin, GND, and digital input for this sensor are connected to the corresponding pins on the microcontroller to enhance circuit circulation.

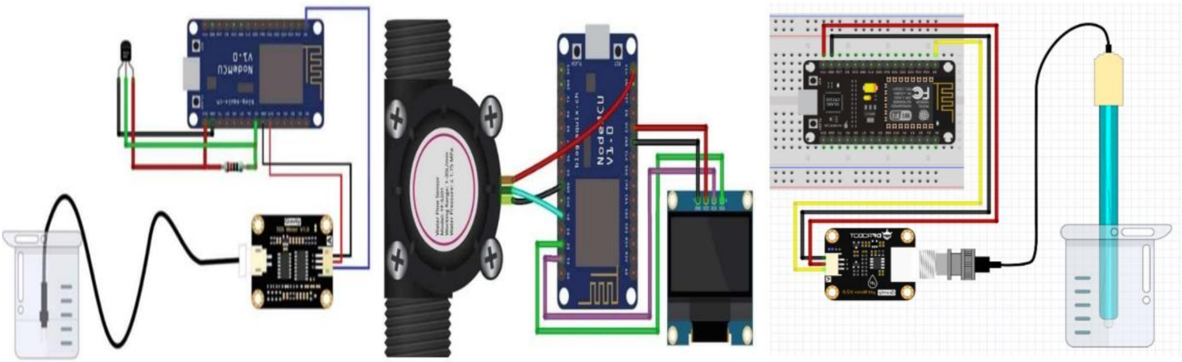

Figure 4: TDS sensor, temperature sensor,water flow sensor LCD 12C and analog Ph sensor setup

2.3 Software Application Setup (Blynk)

Understanding how Blynk is set up as is to present all the data that needs to be collected and measured is critical. Temperatures, pH levels, and TDS levels must all be visible. The TDS value will be in input V1, the EC input will be V2, the temperature will be V3, and the pH value will be V4. All the inputs are virtual pins on the microcontroller that communicate with the Blynk app, which displays all of the numbers on the screen and calculates the data range for each sensor based on the required range. This is shown in figure 7

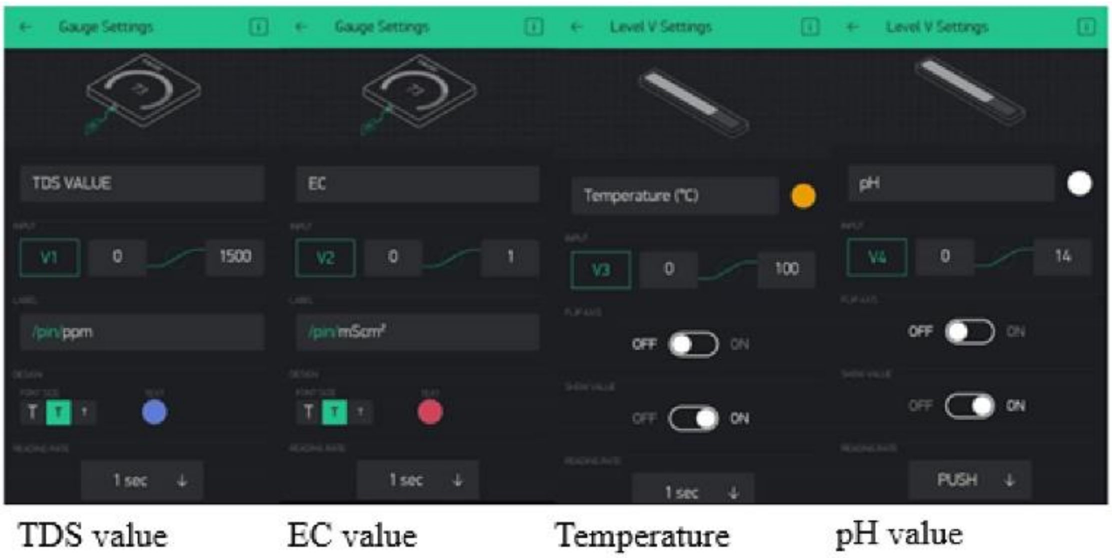

Figure 7: Blynk Setup

The SuperChart Settings in the Blynk software as allow you to examine all the data from the wirelessly linked sensor. The virtual pin that was produced in the previous step must be used to construct datastreams. This is done to show the exact value displayed by the single data widget.

3.4 Components part functionality testing

3.4.1 Node MCU ESP8266

The ESP8266 is a free and open-source software and hardware development platform, often known as the Node MCU (Node Microcontroller Unit). There is also a Wi-Fi module with a SOC and an integrated TCP/IP protocol stack. This allows the microcontroller to connect to the internet. All the sensors will be connected to this microcontroller. Because it lets sensors to send and receive data, the ESP8266 could be used to connect them to an application. Data can be transmitted and received by all sensor modules because they are all transceivers. The microcontroller also has a frequency range of 2400-2484 MHz, which corresponds to the IEEE 802.11 b/g/n standard, which has WAP3 Wi-Fi security (Wi-Fi authentication protocol). Our functionality is crucial for this project since it allows it to connect to the home network and then wirelessly communicate with all the sensors. The image of the components is as in figure 10.

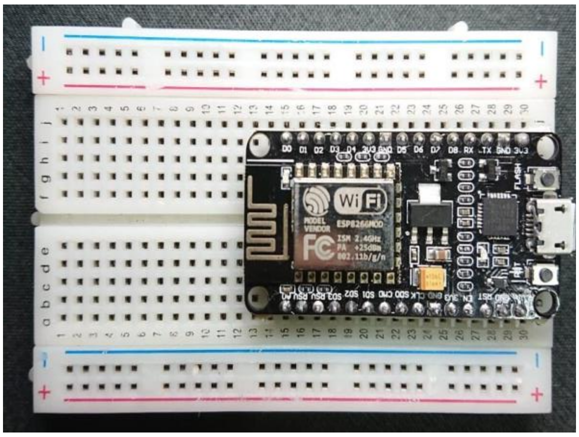

Figure 10: Node MCU ESP8266

3.4.2 Temperature Sensor (DS18B20)

Maxim Integrated DS18B20 is a 1-wire programmable Temperature sensor. It is commonly used to detect temperature in harsh settings like chemical solutions, mines, and soil, among other things. The sensor's construction is tough, and it may also be ordered with a waterproof variant, making installation simple. It has a good accuracy of 5 °C and can measure a wide range of temperatures from -55 °C to +125°C. Each sensor has its own address and only uses one MCU pin to transport data, making it an excellent choice for sensing temperature at various locations without sacrificing too many of your microcontroller's digital pins. The image of the components is as in Figure 11. The pin that connects directly to the microcontroller is displayed below.

- VCC = 3.3 V pin
- GND = GND pin
- GPIO = D5

Figure 11: Temperature sensor DS18B20

3.4.3 Water Flow Sensor

This is a prototype mechanical component that was added. The water flow sensor as shown in Figure 12 below determines the rate of water flow into the tank as well as the volume of water that has been added to fill the tank. When used in connection with the ESP8266 microcontroller, this sensor can show both amount and speed. This is an example of the project's features that can be tracked. It has a plastic valve that allows water to flow through it, as well as a water rotor that signals and monitors water flow. When water passes through the valve, the rotor measures the speed of the water as well as the quantity of water using the valve's rotations. The pin that connects directly to the microcontroller is displayed below.

- VCC = 5 V
- GND = GND pin
- GPIO = D6

Figure 12: Water flow sensor

3.4.4 TDS Level Sensor

A Total Dissolved Solids (TDS) sensor that is shown in Figure 13 could detect and monitor both inorganic and organic components. Total Suspended Solids (TSS), plant debris, and fish faeces were commonly eliminated using aquarium filters. As a result, the total dissolved solids (TDS) test can be used to monitor water quality. This sensor is a submersible waterproof sensor that may be utilized in control systems with a voltage range of 3.3 V to 5.5 V. TDS will provide two sorts of data: a TDS value ranging from 0-1000ppm that indicates the value of solids (nitrate and ammonia) and an EC (Electric Conductance) that indicates the strength of nutrient concentrations for plants and animals. These are the most crucial data points to keep track of because they are the second goal that must be accomplished in order to receive the best quality water for the aquaponics system. Below is the PIN that was used to connect to the microcontroller.

- VCC = 5 V
- GND = GND pin
- GPIO = A0

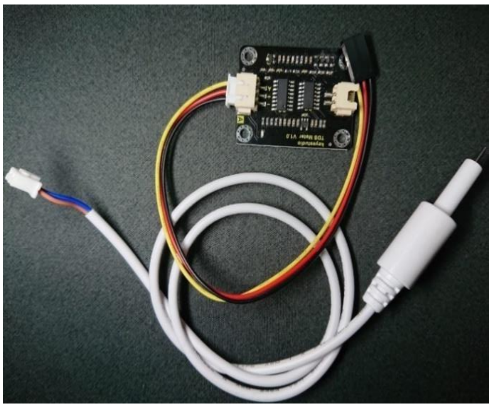

Figure 13: TDS Level sensor

3.4.5 Analog pH Sensor

A pH sensor as shown in Figure 14 below is used to determine the acidity or alkalinity of water, and its value ranges from 0 to 14. The pH value is critical for the health and growth of both plants and fish. A few more points, clean water has a pH of 7. If the pH of water is less than 7, it is called acidic, and if the pH is greater than 7, it is termed alkaline. Surface water systems typically have a pH range of 6.5 to 8.5, while underground water systems have a pH range of 6 to 8.5. The pH value must be maintained and tested at its usual level to accomplish this project. Below is the PIN that was used to connect to the microcontroller.

- VCC = 5 V
- GND = GND pin
- GPIO = A0

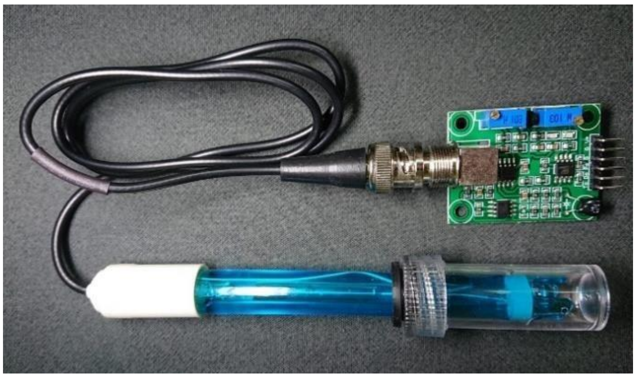

Figure 14: Analog pH sensor

3.4.6 Water Pump

The water pump is already installed at the top of the fish tank, ensuring that water from the fish tank flows continually into the hydroponics. This is important in order to keep the water quality at a consistent level. They use the nutrients in the fish faeces as fertiliser for the plants in the plant tray of the hydroponics system.

The water is filtered from the top before being returned to the fish tank, and the water flow is designed to provide continuous oxygen to the fish. This permits the fish to thrive while the plants gain nutrients and live in an environment free of pesticides. A 5 V water pump is required for the size of the tank used in this project. The image of the water pump is displayed on Figure 15

Figure 15: Water Pump

3.4.7 LCD 12C

This LCD screen as shown in figure 16 below is part of a mechanical component that works in connection with the water flow sensor. It is utilised to show the volume of water in the fish tank as well as the rate of water are pumping into the tank. To summarise, the LCD is intended to display the results of the measurements. Below is the PIN that was used to connect to the microcontroller.

- VCC = 3.3 V pin
- GND = GND pin
- SCL = D1
- SDA = D2

Figure 16: LCD 12C

3. Functionality testing and result analysis

3.1 Prototype implementation

After everything has been said and done, create and implement a single prototype based on all of the requirements previously given. The prototype had been constructed and wired up to meet the project goals that had been set previously at this point. Figure 17 shows a fully functional prototype of the Intelligent Irrigation System Using IoT for Aquaponics Application, complete with all required sensors and functions.

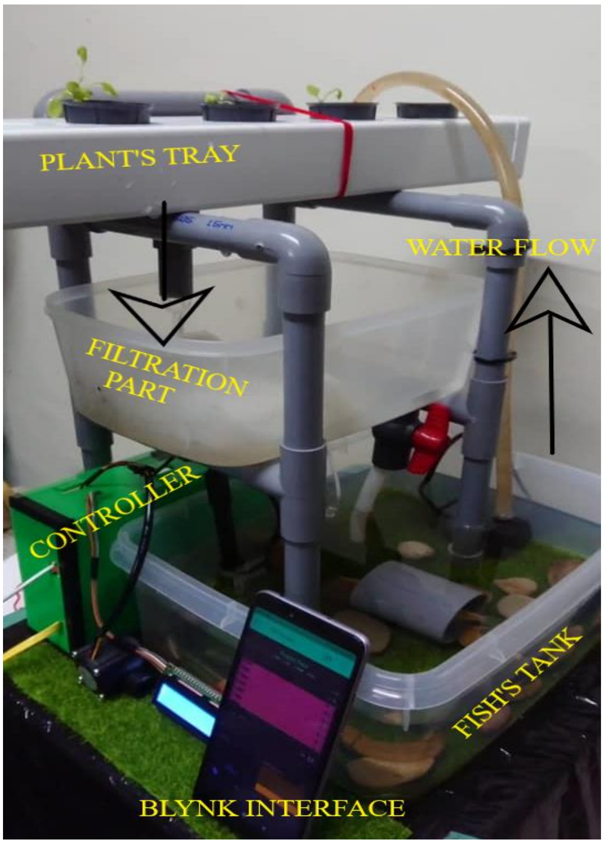

Figure 17: Prototype implementation

3.3 Analysis

3.3.1 Analysis Results

Blynk will show all the data collected throughout the course of the prototype's two-week implementation and operation, containing plants, fish, water, and other aspects. Depending on the graphic outputs that would be displayed and measured, all the project data was divided into groups. TDS, EC, temperature, and pH value are only a handful of the data elements supplied as shown in figure 19. Within 15 minutes of anything happening, all the outcomes were recorded.

Project Data

Created_at	TDS	EC	TEMP	PH
24/10/2021 19:02	72	0.178	26.94	6.59
24/10/2021 19:03	73	0.18	26.94	6.59
24/10/2021 19:05	73	0.18	26.93	6.59
24/10/2021 19:07	72	0.178	26.93	6.59
24/10/2021 19:08	72	0.178	26.94	6.59
24/10/2021 19:10	72	0.178	26.94	6.59
24/10/2021 19:12	71	0.172	26.94	6.59
24/10/2021 19:13	70	0.171	26.94	6.59
24/10/2021 19:15	72	0.178	26.94	6.59
24/10/2021 19:17	72	0.178	26.94	6.59

Figure 19: Analysis Results

3.3.1.1 TDS Level Vs Time

In the Figure 20 below, the TDS sensor reading is represented by a Blynk graph and a numeric number. The sensor data is portrayed as a blue bar graph versus time, whereas TDS value data from smartphones is more intelligible and interpretable when presented digitally. In this graph, the x-axis represents total soluble solids in water, while the y-axis represents time.

After two weeks of 15-minute sessions with the fish tank, the TDS level shows the consistency of the soluble particles in the tank. TDS levels should be between 50 and 150 parts per million in general (ppm). On the first day of installation of this prototype, the tap water in the fish tank had a value of 49 parts per million (ppm).

After two weeks of operation, the value of the prototype is roughly 72 parts per million (ppm). The value growth is caused by elements in the systems, such as fish excrement and plant fertilizers. The water, according to the graph, is still in good shape and adequate for fish and plant growth.

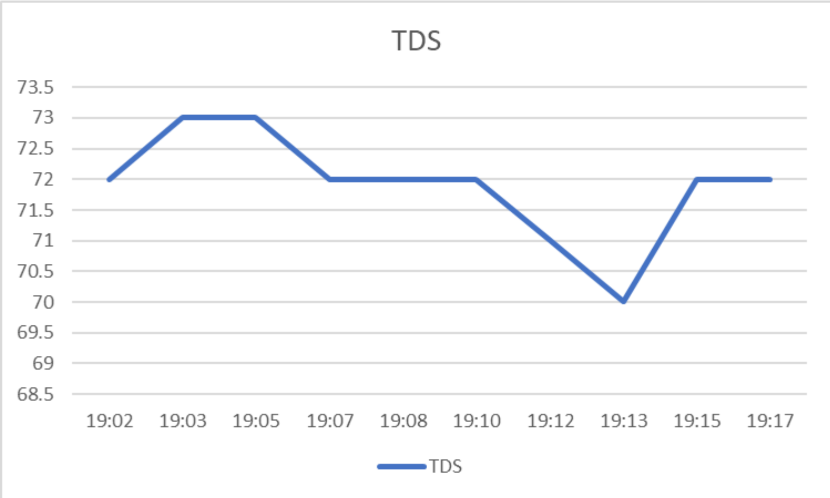

Figure 20: TDS against timeGraph

3.5.1.2 EC Level Vs Time

Another type of data supplied by a TDS sensor is the measurement of the value of the Electric Conductance (EC) level, which indicates the nutrient strength for both fish and plants. The reading indicates the EC value of the water in the fish tank after two weeks of deploying the prototype, which contains fish and baby Pak choi in the process of growing.

To represent the sensor data versus time, a red shadowgraph is constructed from the graph as shown in Figure 21. Even though the digital strategy aims to make the value of EC data from smartphones for users become more valuables, it has drawbacks.

On the x-axis, the EC value in the water is shown, while the y-axis shows the passage of time. In this scenario, the number is steady, ranging between 0.15 and 0.20 mScm2, showing that the plant and fish received enough nutrients to thrive.

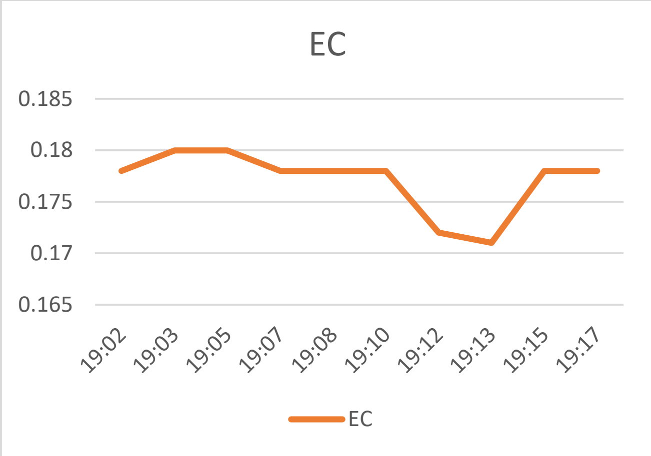

Figure 21: EC against time graph

3.5.1.3 Temperature Vs Time

As a result of the temperature sensor observation, Figure 22 illustrates a Blynk graph and numeric output of the temperature sensor reading. The sensor data as it relates to the passage of time is represented by a green line graph. The digital method, on the other hand, aims to make temperature data from smartphones more relevant.

The temperature of the water is indicated on the x-axis, while the time period is represented on the y-axis. During the 15-minute testing period, the temperature trend remained steady, which was ideal for both the fish and the plant's development.

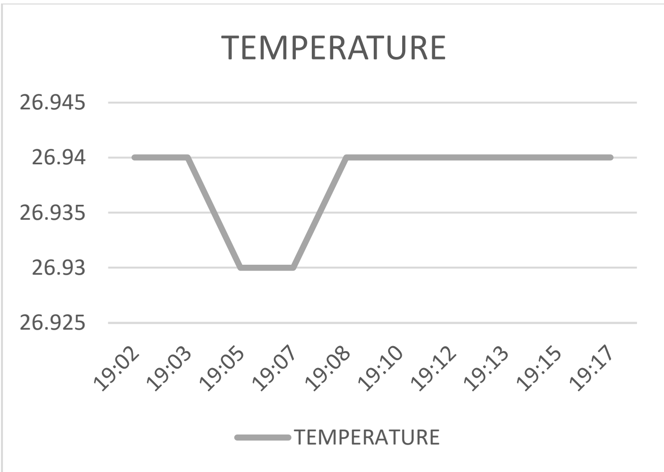

Figure 22: Temperature against time graph

3.5.1.4 pH Level Vs Time

In the Figure 23 below, the pH sensor measurement is represented by a Blynk graph and a numeric number. Sensor data is shown by white line graphs that fluctuate over time, but the digital method makes pH data from smartphones easier to understand. In this graph, the x-axis represents the pH of the water, while the y-axis represents time.

The pH value of 6.59, which is in the range of 6.0-8.0, represents the solution's consistency. According to the National Institute of Standards and Technology, plants require slightly acidic pH levels of 6.0 to 6.5, while fish prefer pH ranges of 6.0 to 8.5. As a result, in an aquaponics system, the pH of the water in the tank is regulated by active bacteria requirements, indicating that the plant is receiving the nutrients it requires to thrive.

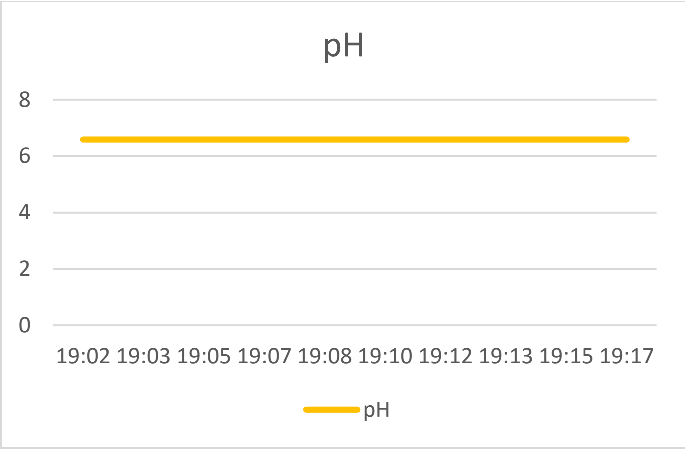

Figure 23: pH SuperChart

3.5.2 Threshold Water Quality for Fish and Plant

The Table 1 below shows the recommended water quality threshold for healthy fish and plant growth, as well as the water quality for keeping the tank clean and clear. When the prototype is utilized, the result is safe for both the fish and the plant because it falls within the appropriate threshold range. Furthermore, both the fish and the plant received balanced nutrition, proving that, based on the project's outcome and the food produced, the prototype could provide nutritious and clean food.

Table 1: Thresholds Water Quality Thresholds

	General	**Result**
TDS level (ppm)	**40-150**	**71-73**
EC Level (mscm2)	**0.15-0.2**	**0.17-0.18**
Temperature (°C)	**30**	**26**
pH Level	**6.5-8.5**	**6.59**

The Blynk data threshold readings are displayed in tabular form. Concentrations of dissolved solids of 40 to 150 parts per million (ppm) are ideal[4]. The TDS sensors detect not only dissolved solids like ammonia and nitrates, but also EC values, which indicate how many nutrients are available for fish and plants to thrive in a safe ecosystem. Depending on the application, the EC should be between 0.15 and 0.2 mScm2.

According to the table 1, the TDS sensor readings for dissolved solids levels are between 71 and 73, and the EC readings are between 0.17 and 0.18, which are ideal values. To improve the accuracy of the TDS sensor's output, the pH value must be accurate and within the range of the threshold required to maintain water quality. To keep the fish and plants in the best possible shape, the pH level should be between 6.5 and 8.5 if the water has appropriate nutrients[5].

The pH value of 6.59 and the temperature of 26 ºC, which is room temperature, are both consistent in the reading. The farmer or user is not obliged to take any action if the readings are within established ranges. They will only act if the sensor's reading falls outside of the acceptable range.

4. Conclusion

In conclusion, plants and fish can both be grown in the same system, saving time and money on logistics and making aquaponics one of the most efficient farming techniques available. Aquaponics provides a lot of advantages over aquaculture and hydroponics alone. The cost of parts is shared, and waste materials are recycled from one device to the next, reducing the overall water consumption of the system and reducing the need for further nutritional supplements. As a result, the food delivery system is less harmful to the environment.

This prototype will also serve as a starting point for Internet of Things (IoT) applications in aquaponic systems, making work easier and allowing for the development of a more comprehensive way to support the agriculture business. The project shows how technology can be integrated with aquaponics to automate tasks such as pumping fish waste into the plant tray, allowing the plant to benefit from the nutrients, cleaning the water for the fish to drink, and monitoring all data to ensure the best water quality for the fish and plant.

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