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Design of Water Quality Monitoring System Based on Internet of Things Technology

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ABSTRACT

Water quality is an assessment of how appropriate water is for a certain use or purpose, taking into consideration various physical, chemical, and biological factors that can affect its suitability. These factors can include pH, turbidity, dissolved oxygen, temperature, and the presence of pollutants or pathogens. The outdated method has been used by scientists and researchers to monitor the quality of water from the sources. The objective of this project is to create an efficient Internet of Things (IoT) system that can various sensors to continuously monitor water quality. The system is implemented using Arduino as the microcontroller, and sensors. A real-time monitoring system that is IoT-based was done to improve the examination process of the water sample. The system device is containing a NodeMCU ESP8266 microcontroller, pH, temperature, and turbidity sensors and uses the Blynk application. The system experiment results show that the device can show different readings based on the variety of water samples from different water bodies.

1. Introduction

Water is the source of life; it has a deep impact on human health. About 70% of Earth's surface is covered with water, yet the amount of fresh water fit for human consumption and usage is as low as 2% of the total volume [1,2]. As society and the economy have rapidly advanced, humans are polluting the water with too much sewage, and it's causing problems for the environment [3,4]. Water quality can change based on location, time, weather, and pollution sources, making it vital to frequently monitor and test the water to ensure it meets the necessary standards for its intended use. The work of scientists, researchers, and water resource managers is crucial in monitoring, preserving, and enhancing water quality [5,6]. Water quality can also be evaluated for the presence of contaminants such as pesticides, herbicides, heavy metals, and algae [7]. Monitoring water quality

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helps to identify the impacts of human activity on the environment and to understand and predict natural processes. It can also be used to support restoration efforts and ensure that environmental regulations are being followed.

In the past, the water quality of an environmental system could be determined through a manual process, where samples of water were collected using tools such as glassware, scoops, and bottles. The samples are then analysed in a laboratory to measure various parameters and determine the water content. This process can take anywhere from 1 to 30 days, depending on the specific measurements being made [8]. Chemical indicators are one of the methods used to determine the acidity of a certain liquid back in the day. These indicators will change colour to indicate whether the water or liquid is acidic or alkaline [9]. It is too hard to decide the pH level accurately because of the limitations of the human eyes. The same goes for temperature where the usage of a physical thermometer has a higher chance of parallax error. The invention of electronic sensors has helped humans, especially researchers to measure and determine the levels of water quality accurately with precise calculations.

The water quality monitoring system was implemented based on the design obtained by the techno-economic analysis. The monitoring system aggregated water quality parameters obtained from water quality sensors (such as DO, pH, salinity, turbidity, and temperature sensors) and remotely collected these data in the cloud database via NB-IoT-based cellular connectivity [10]. The fast development of the Internet of Things has created many opportunities and solutions to many problems, one of which is water quality monitoring. IoT technology is well suited for monitoring water quality and the environment, due to its advanced intelligence, real-time data capabilities, wide range of coverage, ability to simultaneously gather data from multiple sensors, and scalability. It has a wide range of potential applications in this field [11].

Sui H. *et al.,* [12] used the application of NB-IoT technology to monitor the water quality in the city's open water by collecting data from several different points using multiple devices. Shanmugam K. *et al.,* [13] are using the Google Firebase application as a platform for their smart water quality monitoring to make the application more user-friendly and interactive. Hakimi I. *et al.,* [14] are using Arduino Uno and Blynk applications to develop their monitoring device at low cost. Sung W. *et al.,* [15] developed a water quality monitoring system using physiochemical sensors to get more accurate measurements. Prabowo O. *et al.,* [16] designed a remote-operated vehicle system to monitor water quality.

This research used Internet of Things (IoT) Technology with modern features of water quality checking and water usage monitoring systems. All the input will be processed using the Arduino assisted by a Wi-Fi module of NodeMCU to be controlled through a wireless connection from the Blynk apps on the smartphone. Saha *et al.,* [17] used IoT technologies to create an automated fish farm aquaculture monitoring system. The sensor acquisition was conducted by an Arduino microcontroller board, which served as a data processing device and server. Sensing images were captured by Raspberry Pi to monitor water quality using a unique spectral signature of watercolour. Orozco-Lugo *et al.,* [18] developed a cost-effective mobile sensing architecture for flying ad-hoc networks (FANETs) to demonstrate the feasibility of developing remote water quality monitoring systems. Hairol *et al.,* [19] used an Arduino Mega microcontroller board to develop an automated aquaculture monitoring system, which could monitor the water quality closely through the Blynk application on a smartphone. Schmidt *et al.,* [20] developed a low-cost, sensor-equipped buoy system for aquaculture water quality monitoring in coastal farming.

2. Literature Review
2.1 Comparison

The literature survey to develop water quality monitoring systems using different technologies can be seen in Table 1.

Table 1
Comparison of water quality monitoring systems

Authors	Year	Title	Approach	Method	Result
Sui H, Zheng G, Zhou J, Li H, Gu Z	2020	Application of NB-IoT technology in city open water monitoring	Data collection at several different points using multiple devices.	Using the application of NB-IoT to cover a wide area.	Inconsistent reading
Shanmugam K, Rana M, Singh R	2021	IoT-based Smart Water Quality Monitoring System for Malaysia	Application development	Using Google Firebase to create an application.	User-friendly application and interactive
Hakimi I, Jamil Z	2021	Development of Water Quality Monitoring Device Using Arduino UNO	Low-cost device	Arduino IDE and Blynk application.	Easy to use with reliable result
Sung W, Fadillah F	2020	Water Quality Monitoring Using Physio Chemical Sensors	Cost effective, efficiency and easy to use	Arduino processor and ThinkSpeak application.	Accurate result
Prabowo O, Tresnawati Y, Kusumastuti D	2020	Design of Water Quality Monitoring System using Remote Operated Vehicle	Remote operated vehicle	Arduino processor and Laravel PHP server application.	Offering higher data rates to the user.

Most previous studies such as NB-IoT used to monitor water quality require additional cost compared to using Arduino (cost-effective, easy to use, and efficient). Thus, selecting Arduino is one of the most significant water quality monitoring systems.

2.2 Contributions

This research proposes to design of water quality monitoring system based on Internet of Things (IoT) Technology with modern features of water quality checking and water usage monitoring systems. The parameters that will be measured are pH, turbidity, and temperature and the relationship between them using sensors that are designated to each parameter. All the input will be processed using the Arduino assisted by a Wi-Fi module of NodeMCU to be controlled through a wireless connection from the Blynk apps on the smartphone. Finally, this study aims to process and visualize this water quality in real-time for the end-users.

3. Methodology
3.1 Framework

This section will explain the process of how the water quality monitoring system works as shown in Figure 1. The Arduino board, which is based on the ATMega328P microprocessor, serves as the system's primary processor. The characteristics of water quality are gathered using a turbidity sensor, a pH sensor, and a temperature sensor. After being processed by Arduino, the collected data is transmitted to a Blynk application in the smartphone through the ESP8266 Wi-Fi module for real-time monitoring.

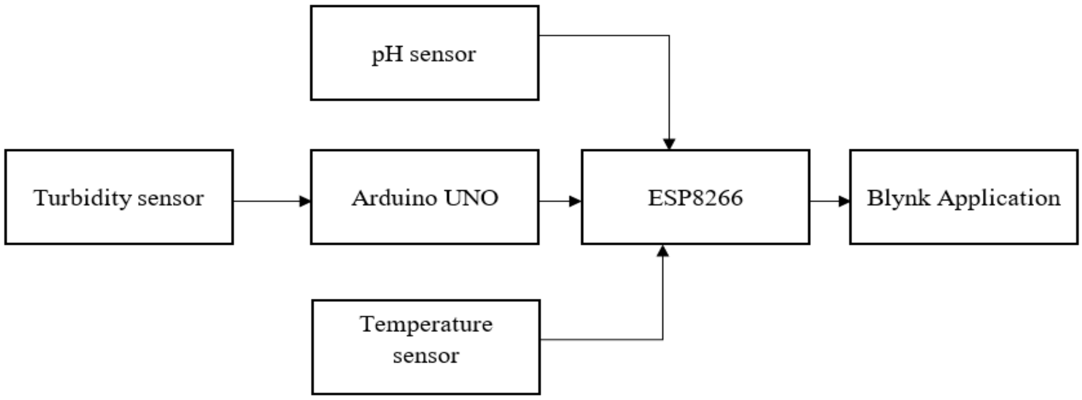

Fig. 1. System's framework flowchart

3.2 Materials

The water samples were gathered from various places such as tap water, ditch, soap water, and lime juice. The parameters that will be measured are pH, temperature, and turbidity. Further testing will be done on the ditch water at the address Lot 1733B, Batu 7, Kampung Sijangkang at coordinates 2.94825738971433, and 101.46138037883536 to monitor the water quality. The water samples are prepared inside plastic bowls and then the samples will be put outside the house to be exposed to the same conditions. Apply to all water samples except for ditch water where it will be gathered every period shown in the result section. The data for all the water samples will be compared to the standard of water quality based on The Engineering Services Department of the Ministry of Health of Malaysia. The standard pH and turbidity that are recommended drinkable are in the range of 6.5 – 9.0 for pH and 5 NTU or less for turbidity [21-24]. The temperature of the water was measured because the water quality also can be affected, especially the aquatic life, by the rate of microbiology growth that depends on the water temperature [25,26]. Table 2 shows the standard range of the sensors.

Table 2
The standard range of the sensors

Parameter	Standard range
pH	6.5 – 9
Temperature	24 – 32°C
Turbidity	0 – 2600 NTU

3.3 Software

The monitoring app on a smartphone serves as the software element of the suggested system. This section describes how to connect to an Esp8266 through Wi-Fi using Blynk applications. Additionally, temperature, pH, and turbidity sensor data can be read by the Esp8266.

3.3.1 Arduino IDE

The Arduino Integrated Development Environment (IDE), shown in Figure 2, also known as the Arduino Software (IDE), includes a code editor, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It communicates with and uploads programs to the Arduino hardware [27].

Fig. 2. Arduino IDE

3.3.2 Blynk application

Blynk (Figure 3) is an IoT platform that allows users to control devices such as Arduino and NodeMCU via a smartphone app on iOS or Android. It allows users to create a graphical user interface by using widgets to display sensor data and remotely control hardware, as well as store and visualize data. It is specifically designed for the Internet of Things [28].

Fig. 3. Blynk application

The flowchart of the system software is shown in Figure 4. The user must first connect to Wi-Fi and the Blynk app on their smartphone to begin the software portion. The Esp8266 component must be interfaced with the Blynk app to connect to Wi-Fi. After reading data from sensors connected to the microcontrollers, the data will then be shown on the user's smartphone.

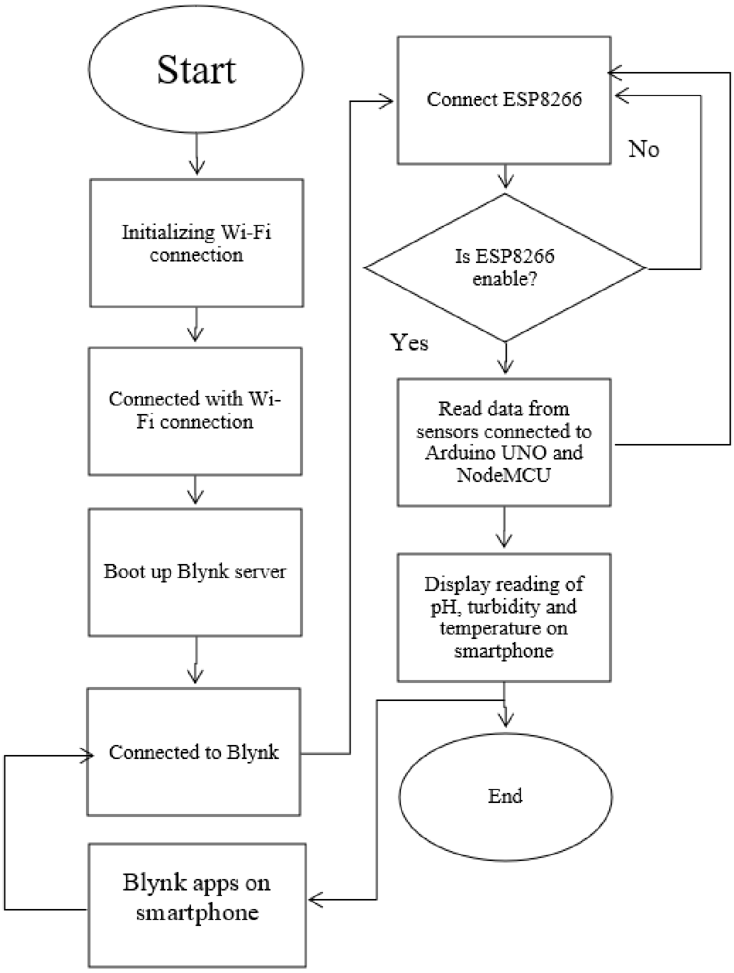

Fig. 4. The software flowchart

3.4 Hardware

For the hardware part, the suggested system required an Arduino UNO R3 controller, an ESP8266 Wi-Fi module, a pH sensor, a turbidity sensor, and a water temperature sensor. Figure 5 illustrates the functioning of the suggested system, which is a water quality monitoring system that is based on software and hardware. The process starts with the initialization of the three sensors, pH, turbidity, and temperature. Then, the sensors will function to read and transfer data through the microcontroller Arduino and send the data to the Blynk application through the Wi-Fi module to be displayed. The equipment includes an Arduino Uno, Esp8266 Wi-Fi module, and smartphone which enable us to continuously determine the characteristics of water, as well as pH and turbidity sensors. The monitoring app on a smartphone serves as the software element of the suggested system.

Readings are straightforward and consistent because every single sensor is submerged in water for testing. We need to use an Analog Digital Converter (ADC), which is already present in the AT Mega 328P in the Arduino Uno, to convert the qualities from simple to advanced and discrete because they are simple. The characteristics will be displayed in the Blynk app, and the Esp8266 will provide microcontroller access to Wi-Fi. Figure 5 shows the flowchart of the hardware.

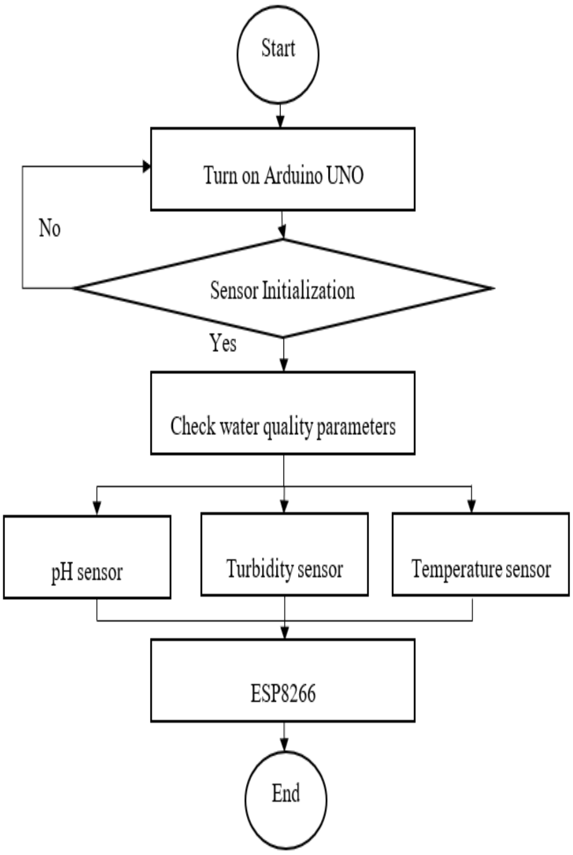

Fig. 5. The hardware flowchart

3.5 Circuit

Figure 6 below shows the circuit diagram of the water quality monitoring system. To explain the diagram, the pH sensor module is connected to the analogue pin in the NodeMCU, and the temperature sensor is connected to the digital pin. Both sensors are powered by the NodeMCU. Meanwhile, the turbidity sensor module is connected to the analogue pin in the Arduino UNO and digital pins 2 and 3 are connected to the Rx/Tx pin of the NodeMCU to be able to connect to the Wi-Fi.

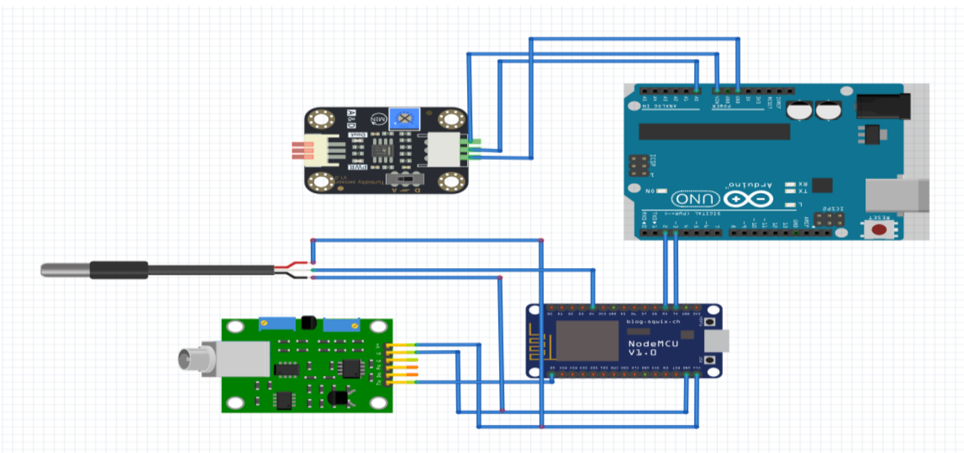

Fig. 6. The circuit diagrams

4. Result and Discussion

4.1 Hardware

Figure 7 shows the condition of the hardware when it was running. The LED light is the indicator that the hardware is functioning as intended.

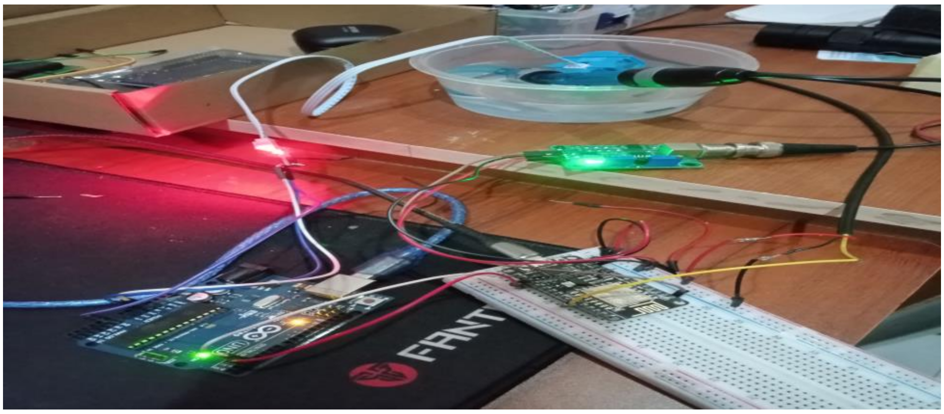

Fig. 7. The hardware results

4.2 Software

The test of the system was done by taking multiple water samples from various water bodies to ensure it was properly functioning. The data was collected on January 30, 2023, at 8.00 am. The reading of the measurements was displayed on the label widget on the Blynk website. To test the accuracy of the sensors, the sensors are set to take 800 samples at one time and then calculate the average value which will be recorded. They then also be 3 times to get the average value. The result of the system is shown in Table 3 while Table 4 is the average value.

Table 3
pH, Turbidity, and Temperature Results

Water sample	pH	Turbidity (NTU)	Temperature (°C)
	7.19	162.31	26.32
Tap water	7.20	156.16	26.18
	7.25	150.04	26.20
	8.14	1724.54	25.89
Ditch	8.25	1756.23	26.05
	8.19	1802.84	26.14
	4.56	725.25	26.43
Lime juice	4.66	731.14	26.48
	4.53	733.26	26.52
	8.02	424.11	26.20
Dish soap water	8.09	437.36	26.23
	8.05	436.43	26.18

Table 4
pH, Turbidity, and Temperature Result (Average Value)

Water sample	pH	Turbidity	Temperature (°C)
Tap water	7.21	16.82	26.23
Ditch	8.27	820.82	26.02
Lime juice	4.5	430.12	26.48
Dish soap water	8.05	359.61	26.2

Figure 8 shows the pH value of the 4 different water types that were tested. The test was done to check whether the sensor was able to detect different pH values of different substances. Tap water has a pH value range between 7.19 – 7.25 with an average of 7.21 which is ideal for domestic usage. The pH of lime juice is at the lowest pH value with an average of 4.5 as lime is containing citric acid which is acidic. The soap water and ditch water have pH values above 7 with the soap water having an average value of 8.05 because soap is alkaline and ditch water 8.27.

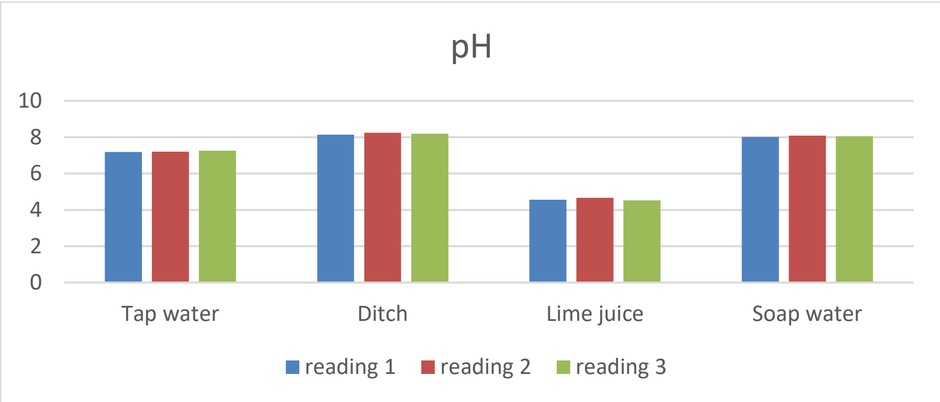

Fig. 8. pH of 4 different types of water

Figure 9 shows the temperature of the 4 different types of water. Based on the observation, each water type has a quite inconsistent trend in the graphs. The change in temperature is because of thermodynamic equilibrium. When the water samples are put in the plastic bowls, and the temperature sensor merges into the water, heat transfer between the medium and surroundings happens [29]. At the same time, when mixing lime juice and dish soap into the water, exothermic reactions happen and cause the temperature to increase.

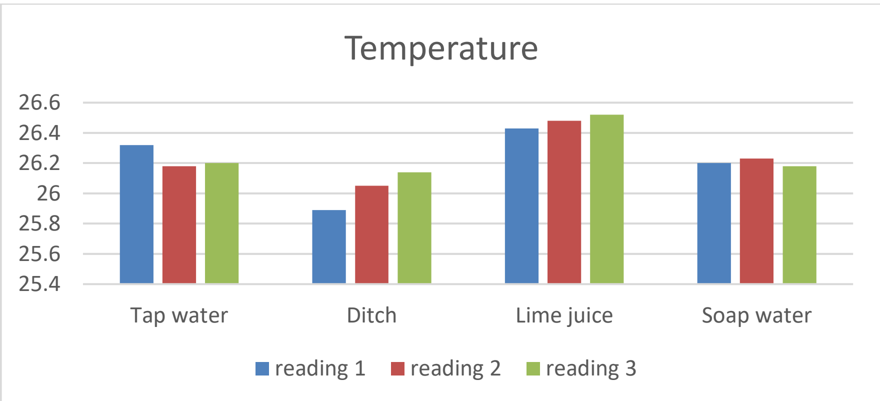

Fig. 9. Temperature

Figure 10 shows the turbidity of water for all 4 types of water. The turbidity sensor is shown to be able to detect the murkiness of water. Ditch water has the highest turbidity with an average value of 820.82 NTU. This is because the ditch water contains various kinds of substances in it including mud, algae, and other microorganisms. Meanwhile, tap water has the lowest turbidity value with an average of 16.82 NTU as the water is crystal clear and safe for domestic usage.

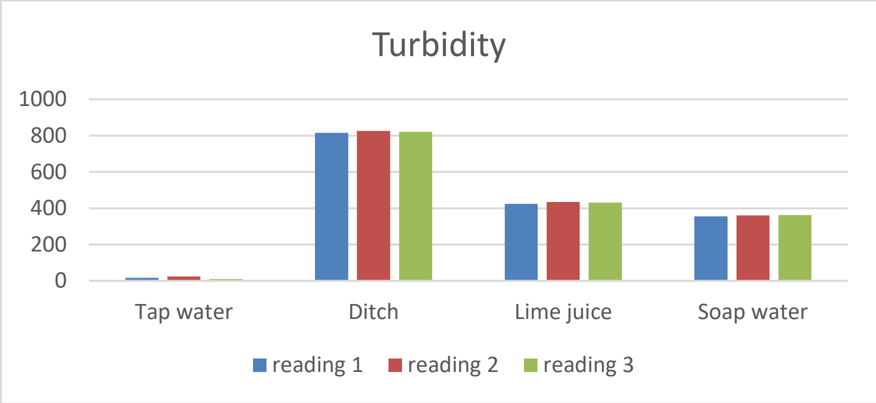

Fig. 10. Turbidity

Figure 11 shows the results of the label widget on the Blynk website during the testing of the system. The NodeMCU microcontroller is to connect the system to the internet to monitor the measurement of the water samples using the Blynk website.

Fig. 11. Blynk website during testing

Table 5, Table 6, and Table 7 show the data obtained from ditch water on January 30, 2023, for 3 different period monitoring processes at 8.30 am, 1.30 pm, and 7.30 pm. This section will discuss the results gained from the testing.

Table 5
pH values gained for 3 different period monitoring process

Water sample	8.30 am	1.30 pm	7.30 pm
Tap water	7.19	6.97	7.09
Ditch	8.23	7.41	8.25
Lime juice	4.49	4.72	4.66
Dish soap water	8.01	7.85	8.11

Table 6
Temperature values gained for 3 different period monitoring process

Water sample	8.30 am	1.30 pm	7.30 pm
Tap water	27.25	29.38	28.53
Ditch	25.56	30.91	27.81
Lime juice	26.63	29.42	28.56
Dish soap water	26.69	29.35	28.31

Table 7
Turbidity values gained for 3 different period monitoring process

Water sample	8.30 am	1.30 pm	7.30 pm
Tap water	16.21	20.56	18.27
Ditch	816.54	1288.35	1089.26
Lime juice	721.98	913.69	822.42
Dish soap water	424.74	591.28	468.63

The results from Table 5, Table 6, and Table 7 were plotted on graphs as shown in Figure 12, Figure 13, and Figure 14 respectively. Figure 12 shows the change in pH value on that day for 3 different periods. The pH value throughout the experiment lies between over 7 to close to 9 except for lime juice. All the samples were at their respective lowest pH at 1.30 pm respectively. The change in pH value is caused by the concentration of hydrogen ions present in the water [24]. When the concentration of hydrogen ions is high, the pH value decreases and vice versa. During midday, the sun was at its peak position on the Earth which caused temperatures to increase. This caused the molecular vibration of the water to increase which results in the ability of water to ionize and form more hydrogen ions [30].

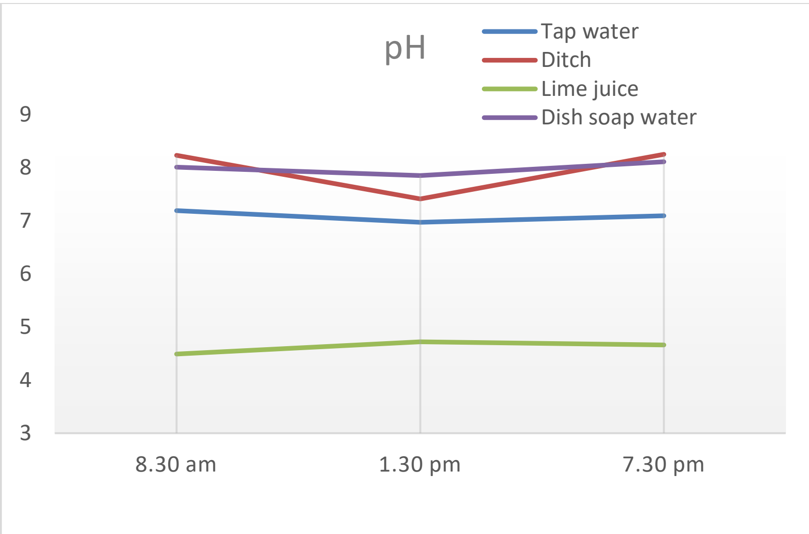

Fig. 12. pH graph

Figure 13 shows the graph of the temperature of the water during the monitoring process. From the result, it shows that the trend of the temperature of the samples was similar where first the temperature increased at the beginning and decreased at the end. The highest temperature recorded is 30.91°C at 1.30 pm and the lowest temperature is 25.56°C at 8.30 am from the water ditch sample. On that day, the sun was at its peak at midday at 1.30 pm. In the afternoon, it starts getting cloudy from 3.30 pm onwards and causes the temperature to drop drastically until 7.30 pm.

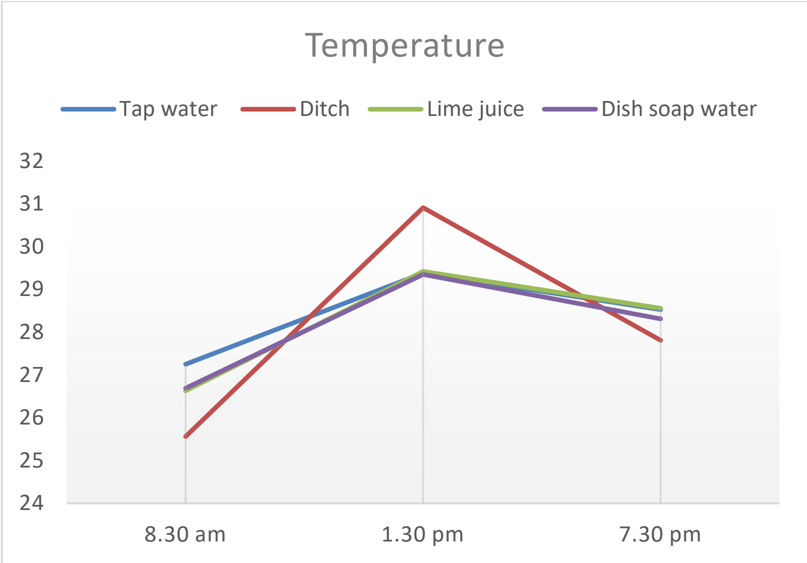

Fig. 13. Temperature graph

Figure 14 shows the graph of turbidity of the water changes throughout the day. The change of turbidity may be caused by water flow in the ditch which can drag away or bring in residues like mud or other solids substances to the testing spot. It also can be affected by human activities like deforestation. The graph shows that the turbidity is at its highest during midday when the temperature is also the highest. This condition shows that the temperature also affects the turbidity of the water. The reason for this to happen is the high temperature causing disruption to the sensors. Changes in temperature can cause variations in the refractive index of water, which can in turn affect the accuracy of optical sensors used to measure turbidity [31].

The other factors that temperature can impact turbidity are the growth of algae and the decomposition of organic matter, which can increase the number of suspended particles [32] which may not be possible for this experiment since it was held for a short period of time.

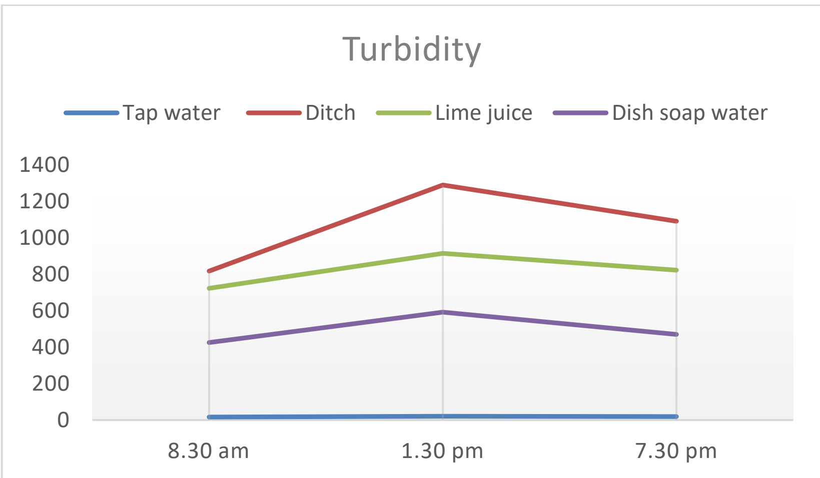

Fig. 14. Turbidity graph

5. Conclusions

The water quality monitoring system design that is based on the Internet of Things feature is low-cost, reasonable, rigorous, and functional. The hardware can connect to the internet and the system can show the readings of the parameters in real-time from the Blynk website. Based on the results, it can be concluded that the temperature of the water is affecting the condition of the water in terms of pH value and turbidity. The temperature is inversely proportional to the pH value. As the temperature increases the pH value decreases. The temperature is directly proportional to the turbidity, and it stays true even though the turbidity sensor is affected by the temperature. A few improvements could be made to the system such as the design of the hardware where it can be easily carried around. Use even more advanced and high-sensitivity tolerance sensors to get more accurate results.

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