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IoT-Water Quality Monitoring System Using ESP32

Norsuzila Ya'acob[1,2,*], Nur Shamimi Akmar Samzulkamal[1], Amirul Asraf Abdul Rahman[1], Noraisyah Tajudin[1], Azita Laily Yusof[1,2], Wan Norsyafizan W. Muhamad[1,2]

[1] School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[2] Wireless Communication Technology (WiCoT), School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

ARTICLE INFO	**ABSTRACT**

Water contamination is fast becoming a worldwide challenge as a result of soaring water demands due to rapid urbanization and population growth. Water quality must be evaluated daily to meet the demand for clean water. Traditional techniques have been used in monitoring water quality. However, these techniques have several limitations, including being labor-intensive, lacking real-time data, and having significant operating and equipment expenses. This project aims to develop a monitoring system using ESP32 that can monitor real-time water quality. The system comprises ESP32 as a microcontroller, pH sensor, turbidity sensor, and temperature sensor to measure water quality such as pH, turbidity, and temperature. The sensors are connected to the ESP32 and interfaced with it. The data of the measured parameters were collected by NodeMCU ESP32 and sent to the Blynk application. By the end of the project, users can monitor the parameters, i.e., pH, turbidity, and temperature, on their smartphones through BlynkApp. The outcome reveals that temperature affects the turbidity and pH of the water, with the temperature directly proportional to turbidity. Meanwhile, the pH of the water decreases as the temperature rises.

Keywords:
Water Quality Monitoring; pH; Turbidity; Temperature; ESP32

1. Introduction

Humankind has been given water as one of the most important natural resources. According to published information by the World Health Organization (WHO) and UNICEF in 2017, more than 785 million people worldwide do not have access to basic water services, and more than 884 million do not have safe drinking water [1]. Almost half of them dwell in Sub-Saharan Africa, with the remaining fifth in Southern Asia. Clean water is important, as having access to clean water and sanitation eliminates the risk of contracting various diseases [2,3]. Millions of people die every year due to diseases brought on by a lack of clean water, sanitation, and hygiene. One of the causes of this is public and administrative illiteracy, as well as the absence of a system to check the quality of the water, which causes major health risks.

[*] *Corresponding author.*
E-mail address: author.mail@gmail.com

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Although Malaysia is a tropical country with plenty of rain throughout the year, the country nevertheless faces water shortages and water quality challenges. Malaysia's river water quality has long been a source of concern for local governments, government agencies, and the general population. Recognizing the severity of the threat to river water, Malaysia has undertaken tremendous efforts in recent years to restore river water quality. Malaysian environmental management began with the passage of the Environmental Quality Act in 1974 and the establishment of the Department of Environment (DOE) in 1976. Today, the DOE, the Department of Irrigation and Drainage (DID), and the corresponding state-level agencies operate over 1000 manual and automatic water quality monitoring stations in 146 basins across Malaysia [4].

The river water is collected, and information on the water quality parameters is obtained from the water quality laboratory. However, these methods are expensive and time-consuming because of the numerous samples required. Hence, the Wireless Sensor Networks (WSN)-based real-time water monitoring systems have become increasingly popular due to the technological advances in data and information acquisition through the sensor node. Water quality monitoring has piqued the interest of researchers in this twenty-first century. The open issues in wastewater analysis are mainly related to the complex and expensive equipment often required, unsuitable for the IoT and pervasive paradigm, and the lack of an anomaly detection step [5]. This research aims to develop an efficient, cost-effective, real-time water quality monitoring system that integrates with the Internet of Things (IoT).

In its most basic form, the IoT is the concept of linking physical devices, machinery, software, and materials to the Internet [6]. It is a flexible worldwide network system in which intelligent devices and entities are used with controllers, sensors, programming, and networking to improve connection, collecting, and data sharing. IoT systems will become more than the sum of their parts by sharing and interacting with the common data provided by separate pieces [7]. Each system node is considered intelligent and uses a few resources such as processing, memory capacity, and electricity. The IoT approach is extremely useful for achieving real-time sensor data monitoring. In this study, ESP32 was used as a microcontroller and interfaced with temperature, pH, and turbidity sensors.

A water quality monitoring system usually monitors water conditions and quality, including water temperature, pH, turbidity, conductivity, and dissolved oxygen (DO) in bays, lakes, rivers, and other water bodies [8]. The parameters affecting water quality, such as temperature, turbidity, pH, dissolved oxygen, conductivity, and salinity, must be considered to monitor water quality. Hence, temperature, pH, and turbidity were the parameters selected to develop a hardware system that can be used to monitor real-time water quality. Due to the budget constraint, sensors were chosen for their simplicity, measurability, convenience, and cost-effectiveness.

This project focuses on building a real-time water quality monitoring system connected to the IoT and can be used to get early alerts before the water quality worsens. Water quality monitoring can aid in the early identification of water contamination by analyzing parameters such as temperature, turbidity, and pH. This project can be a practical solution for locations without a water quality laboratory to lessen the need for on-site staff while lowering costs. The temperature, turbidity and PH value can be monitored online from any part of the world using IoT.

The remainder of this paper is organized as follows Section II explains the methodology performed for this study which is verified by the simulation results and discussion in Section III. Finally, concluding remarks are summarized in Section IV.

2. Methodology
2.1 Material
2.1.1 Study area

The chosen study area is Triang, Pahang (3°15'42.7"N 102°21'40.1"E). Water samples were obtained from Sungai Triang, which flows from Jelebu, Ulu Kelawang, Negeri Sembilan, to Sungai Pahang in the state of Pahang. Data were gathered on January 27, 2022, January 31, 2022, and February 1, 2022, for a 9-hour monitoring period. The study area was chosen because there is an Orang Asli village nearby, and the villagers sometimes bathe and fish in this river. Due to the regular daily activities practiced in this river, it is important to study the water quality of the river. In 2015, Sungai Triang was classified as Class II with a WQI of 83 [7].

2.1.2 Software

The software used in this study is Arduino IDE, Fritzing, and Blynk App. The Arduino Integrated Development Environment (IDE) is a cross-platform program with C and C++ features. This software uses NodeMCU ESP32 as the microcontroller in the system. Moreover, the Fritzing software was used to draw the circuit connection used in this study. Fritzing is free software for designing electrical hardware for users ready to progress beyond prototyping to make a more permanent circuit. Lastly, the Blynk application is used to notify users of the sensor condition from time to time. Data are sent to the application to allow users to be updated daily. The application also helps to display the percentage of the sensor conditions, which the users can view as they wish.

2.1.3 Component used

i. NodeMcu ESP32
NodeMcu ESP32 is an open-source IoT platform that does two functions at once: first, processing sensor readings, and second, transmitting the data to the internet via the ESP32's built-in Wi-Fi module. With an operational temperature range of –40°C to +125°C, the ESP32 can perform reliably in industrial conditions.

ii. Turbidity sensor (Grove - Turbidity Sensor Meter for Arduino V1.0) 101020752
A turbidity sensor measures the turbidity (or cloudiness) of water caused by suspended solid particles. The particle density in the water is calculated using the quantity of light reflected. It can measure turbidity ranging from 0 to 3000 NTU. The range for turbidity is 0 to 2600 NTU. 0 NTU indicates that the water is clear while 2600 NTU is when the water is murky

iii. Temperature sensor (DE18B20)
DS18B20 is a one-wire waterproof temperature sensor that is programmable. It has an accuracy of ±0.5°C and can monitor temperatures ranging from –55°C to +125°C. It provides temperature values ranging from 9 to 12 bits.

iv. PH sensor (PH Electrode Probe E-201-C)
The pH probe sensor is used to determine how much alkalinity and acidity are present in water and other liquids. The pH Sensor resembles a rod, generally made of glass, with a "Glass membrane" tip. This membrane contains a buffer solution with a predetermined pH (usually pH = 7).

2.2 Method
2.2.1 Block diagram of the system

Figure 1 depicts the overall block diagram of the system. The block diagram shows several devices with their sensors, and the data received are gathered at the NodeMCU ESP32 core controller. NodeMcu ESP32 is an open-source IoT platform that does two functions at once: first, processing sensor readings, and second, transmitting the data to the internet via the ESP32's built-in Wi-Fi module.

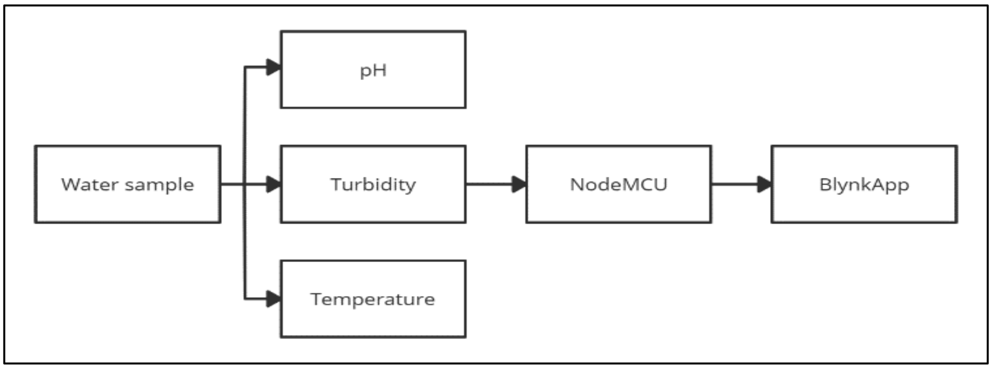


Fig. 1. Block diagram of the system

2.2.2 Project flowchart

Figure 2 shows the flowchart of the project, which starts by interfacing NodeMCU ESP32 and the sensors. The three sensors involved in this system are temperature, pH, and turbidity. As the sensors are connected, the turbidity sensor will start measuring the cloudiness of the water due to suspended solids and plankton in the water column. The pH sensor measures the pH of the water, and the temperature sensor measures the water temperature. Once the reading of these parameters is measured, all data will be sent and displayed on the Blynk app.

Once data are sent to the Blynk app using a Wi-Fi connection, the measured values of pH and turbidity will be compared with predefined values.A message stating that "pH is too low" will appear in the Blynk app if the pH value is less than 7, which denotes that the environment is becoming more acidic. If the value of turbidity approaches 2500 NTU, a notification will pop up stating that “Turbidity is too high,” as the ideal NTU of untreated water can range from 70 to 2500 [8].

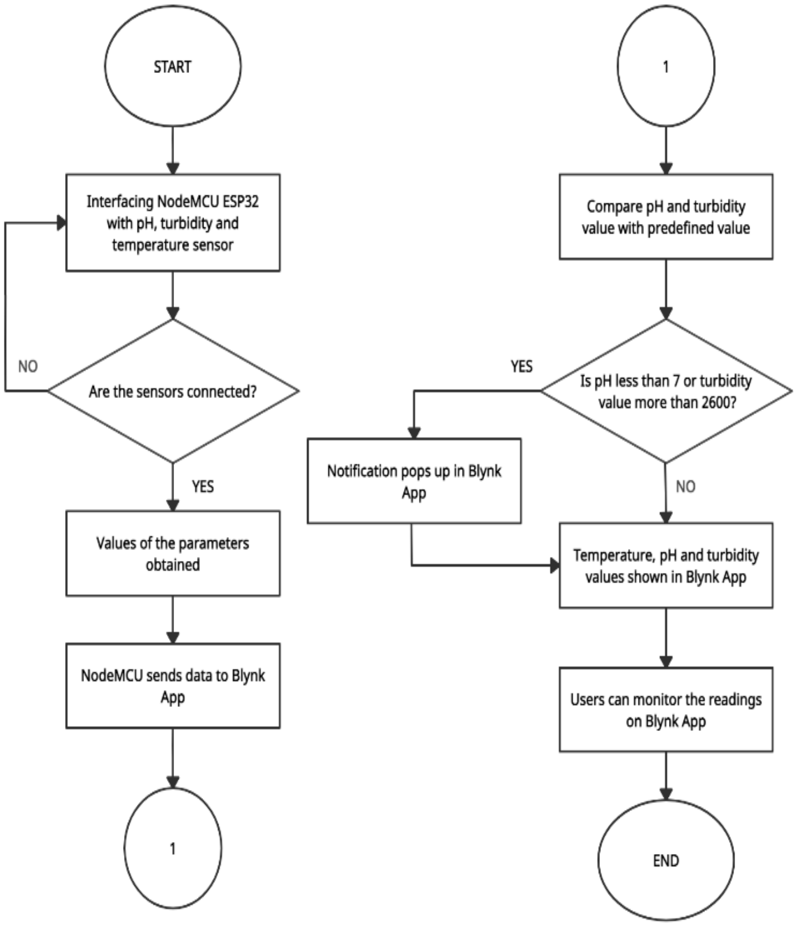
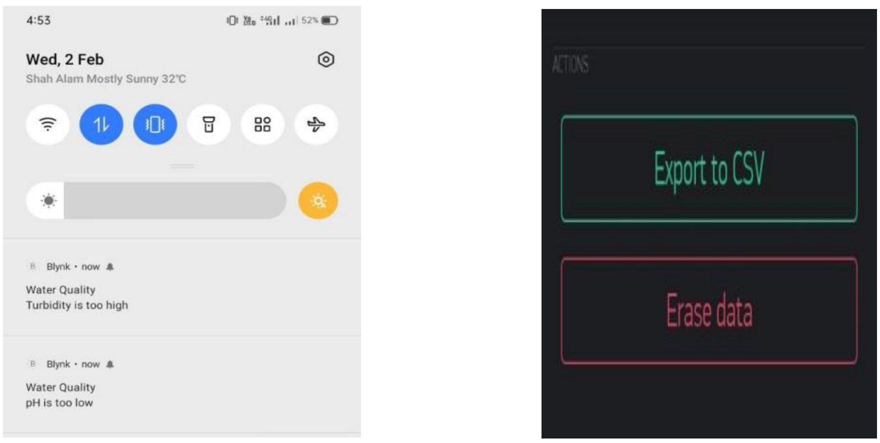


Fig. 2. System flowchart

Figure 3 (a) depicts the notifications of the system. However, if the values obtained do not meet the set conditions, no notifications will pop up on the application. After this stage, users can monitor the parameter values in the Blynk app installed on their phones. Users can also save the data in their database for future monitoring processes, as shown in Figure 5 (b).



(a) (b)

Fig. 3. (a)Notifications of the system (b)Data export option on Blynk app

The pH and turbidity sensors are calibrated before use to ensure the accuracy of the measurement. Once the sensors are ready and function well in the hardware, they are dipped into the river water to get the values.

2.2.3 *Factor selection*

The factors selected to monitor the water quality are pH, temperature, and turbidity as shown in Table 1. The pH is selected as a factor because water acidity can be measured. The pH scale ranges from 0 to 14. A solution with a pH less than 7 and more H^+ than OH^- ions is called an acidic solution, while a solution with a pH greater than 7 and more OH^- than H^+ ions is called a basic solution [9].

Temperature is a significant factor in monitoring water quality due to its impact on water chemistry [10]. The average kinetic energy of molecules of water is measured by temperature. It is well known that temperature significantly impacts pH and turbidity [11]. Temperature is measured in degrees Celsius or Fahrenheit on a linear scale.

Subsequently, turbidity is selected to measure a liquid's relative clarity [12]. It involves measuring the amount of light dispersed by material in the water when light is shined through a water sample [13]. The turbidity increases proportionate to the increase of scattered light intensity. High turbidity can harm aquatic life and cause several human illnesses [14].

Table 1
Sensors range and accuracy

Parameter	Range	Accuracy
pH	0 to 14	± 0.1
Temperature	-55°C to +125°C	± 0.5 ° C
Turbidity	0 – 3000 NTU	± 3 NTU

Based on the range of the multiple sensors, a series of the new range was determined to indicate that the river is in good condition, as shown in Table 2.

Table 2
Safe range of the sensors

Parameter	Safe range
pH	7 - 9
Temperature	25 - 30° C
Turbidity	0 – 2600 NTU

2.2.4 Circuit

Figure 4 shows the schematic circuit was designed using Fritzing. The components such as the temperature sensor, pH sensor turbidity sensor, and resistor are linked to various pins on the NodeMCU board. A 5V-regulated power source is used to power the NodeMCU ESP32 module. All the output pins of the sensors are connected to the analog output pin of the microcontroller.

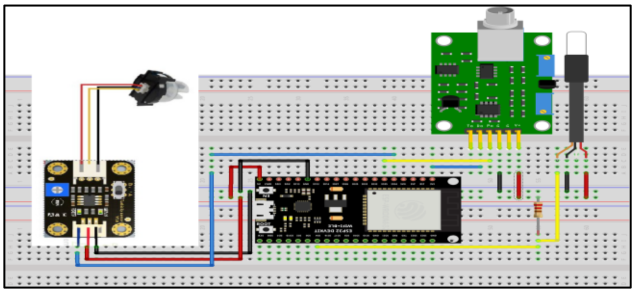
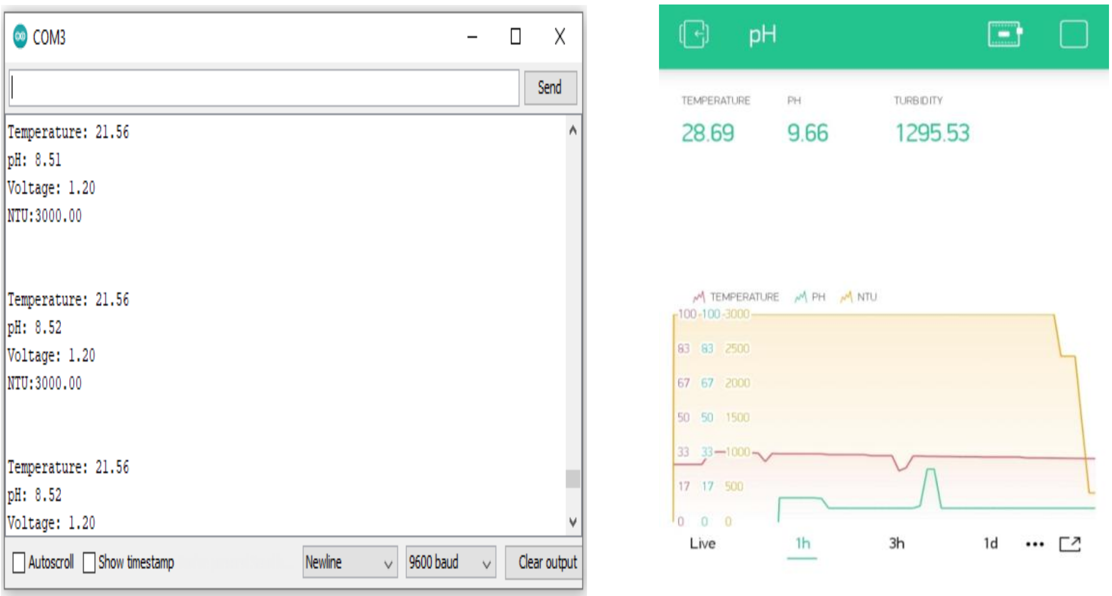


Fig. 4. Schematic circuit

3. Results and Discussion

3.1 Sensors Testing

The temperature and pH of the sensor were tested with various types of water and temperatures to ensure that it functions properly. Hot and cold water with ranging temperatures were used. Meanwhile, the pH sensors were tested using buffer solutions with a range of pH values from acid to alkaline to ensure accuracy. Figure 5 (a) shows some of the results of water pH and temperature testing. The NodeMCU ESP32 microcontroller is used to monitor and link the water quality monitoring system to the Blynk application. The measured data was shown using the Blynk program, and the result was saved as a CSV file in the database. Figure 5(b) shows the Blynk Application during testing monitoring.



(a) (b)

Fig. 5. (a) Result of testing (b) Blynk application during testing

3.2 Real-time Monitoring Results

Table 3 shows the data gathered on January 27, 2022, for a 9-hour monitoring period. The monitoring process was done on January 27, 2022, January 31, 2022, and February 1, 2022. The reading for January 27, 2022, was taken after 9.00 a.m. due to a technical problem. This section discusses the results obtained from the surface pressure measurement study. Tables 3, 4, and 5 were generated and plotted on graphs to observe the association between the parameters.

Table 3
Temperature values obtained for 3 days monitoring period
(January 27, 2022, January 31, 2022 & 1 February 1, 2022)

Time	Day 1	Day 2	Day 3
7.30 am	-	24.54	25.01
8.45 am	-	25.96	25.74
9.30 am	26.36	26.54	25.81
10.45 am	26.79	26.79	26.04
11.20 am	27.31	26.81	26.73
12.30 pm	28.54	27.14	27.21
1.40 pm	28.56	27.65	27.43
2.45 pm	28.32	28.14	27.65
3.25 pm	27.71	27.57	27.54
4.30 pm	26.93	27.54	27.39
5.30 pm	26.55	26.91	26.43
6.45 pm	26.51	26.76	26.03

Table 4
Turbidity values obtained for a 3-day monitoring period
(January 27, 2022, January 31, 2022, and February 1, 2022)

Time	Day 1	Day 2	Day 3
7.30 am	-	853.21	879.32
8.45 am	-	965.65	1014.53
9.30 am	835.89	1464.87	1521.21
10.45 am	905.53	1765.83	1321.47
11.20 am	962.63	2006.71	2015.32
12.30 pm	1276.82	2154.65	2171.36
1.40 pm	1563.32	2375.65	2378.12
2.45 pm	2023.56	2243.76	2142.83
3.25 pm	1978.43	2198.32	1872.76
4.30 pm	1974.34	1972.81	1779.25
5.30 pm	1654.7	1851.62	1763.7
6.45 pm	1789.32	1696.88	1539.54

Table 5
PH values obtained for a 3-day monitoring period
(January 27, 2022, January 31, 2022, and February 1, 2022)

Time	Day 1	Day 2	Day 3
7.30 am	-	8.39	8.42
8.45 am	-	8.43	8.29
9.30 am	8.32	8.41	8.35
10.45 am	8.18	8.34	8.31
11.20 am	8.21	8.21	8.03
12.30 pm	7.69	7.42	7.83
1.40 pm	7.54	7.33	7.64
2.45 pm	7.73	7.13	7.23
3.25 pm	8.01	7.65	8.12
4.30 pm	8.13	8.19	8.17
5.30 pm	8.27	8.24	8.22
6.45 pm	8.28	8.31	8.29

3.2.1 Temperature

Figure 6 depicts the variation of temperature from 24°C to over 28°C. Table 3 reveals the maximum measured temperature by the sensor of 28.56°C at 1.40 pm on January 27, 2022, and the minimum temperature of 24.54°C at 7.30 am on January 31, 2022. The sun was at its peak during the day, and the highest temperatures of the day were recorded between 12 p.m. and 3 p.m. when collected solar energy was at its highest. Since Malaysia is a tropical country, it is not uncommon for the temperature to reach 30°C. Ambient temperature, the amount of shade, soil erosion increasing turbidity, and thermal pollution from human activity are factors that affect water temperature [15].

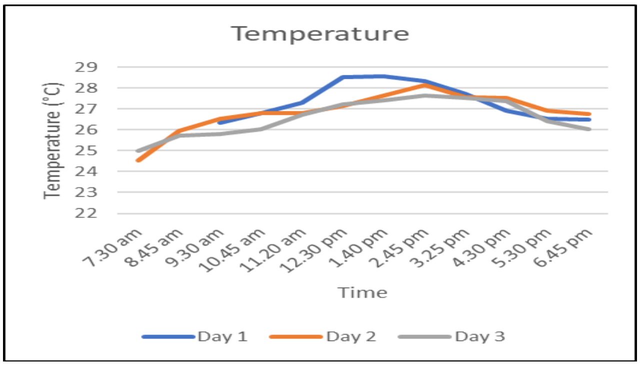


Fig. 6. Temperature variation

3.2.2 Turbidity

Figure 7 shows the variation of turbidity values recorded during the monitoring process. The graph indicates that turbidity increases until the afternoon and decreases towards the evening. When the stream moves, the kinetic energy of the high-speed stream can resuspend river bottom sediments and convey suspended solids, resulting in high turbidity levels [5]. Suspended sediments settle on the riverbed in still water, resulting in decreased turbidity values.

It is observed from Figure 7 that the turbidity values in three days are the highest from 2.45 pm to 3.25 pm when the temperature is also at its highest. The highest turbidity is 2378.12, recorded on February 1, 2022, as shown in Table 4. Turbidity and temperature have a positive relationship. Suspended particles have a larger heat reserve than water and absorb more heat, resulting in a higher recorded temperature [16]. Turbidity values are at their lowest at low measured temperatures. Due to changes in season, stream flow, environment, and climate, the precise turbidity value is hard to define. Moreover, the readings change slightly every second during measurement. However, a value of turbidity less than 3000 NTU is considered ideal.

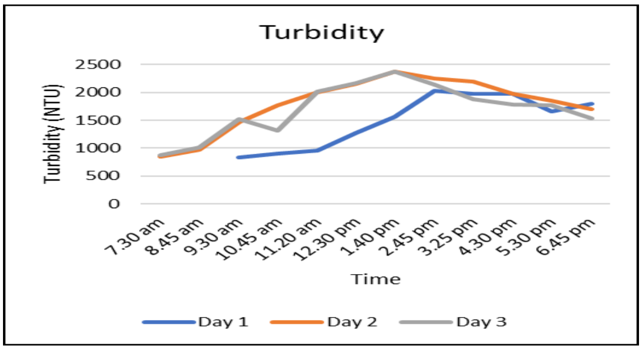


Fig. 7. Turbidity variation

3.2.3 PH

Figure 8 shows the pH values in 3 days. The pH values throughout the observation hours lie between 7 to 9. The pH of the river will decrease due to the emission of H^+. However, at greater pH, the balance shifts to the left, favoring the production of carbonic acid, resulting in reduced H^+, raising the pH of the river. Table 5 shows that the lowest pH measured is between 12.30 pm to 3.25 pm. This happened due to the increased water temperature, as a drop in pH can be caused by a rise in temperature [17]. This is supported in [18] as the pH value will change due to the changes in the ion concentrations caused by temperature changes. As the temperature increases, so do the molecular vibrations, allowing water to ionize and generate additional H^+, resulting in a pH drop [5].

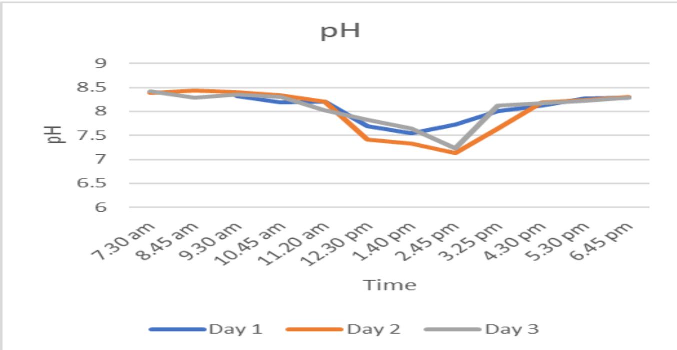


Fig. 8. pH variation

However, this does not imply that the water becomes acidic as the temperature rises. The acidity of water does not change with temperature because the ratio of hydrogen to hydroxyl ions remains the same [19]. The pH of a solution can changes depending on the water temperature without making it more acidic or basic [20]. Throughout the observation period, pH values change dramatically throughout the day, and site readings might fluctuate dramatically every second due to the degradation of leaves at the bottom of the river, releasing carbon dioxide and causing the production of carbonic acid [21]. Figure 9 shows a live data view of the water monitoring quality system. In the application, the value widget for temperature, pH, and turbidity of real-time data is included to make it easier for the user to know the exact values instead of acquiring them from the graph. The graph shows the trend of the readings, and it is observed that the values are infatuated every few seconds.

Fig. 9. Blynk App

3.3 Temperature, Turbidity, and PH Comparison

Table 6 shows the comparison result for temperature, turbidity, and PH. The variation of temperature is within 24°C to over 28°C for both researches. The maximum recorded temperature was within the range of 27.73°C – 28.56°C from the noon to mid-afternoon. Heating of the earth by the sun is cumulative throughout the day and the maximum temperature of the day is achieved from noon to mid-afternoon, between 12 p.m. and 3 p.m., when accumulated solar energy is at its maximum [22].

According to Table 6, it is evident that the turbidity levels are higher during the afternoon. Indeed, both temperature and turbidity readings are higher in the afternoon. It should however be noted that the exact turbidity value is difficult to pinpoint due to natural variation in season, local geology, river flow, weather, and climate, and readings vary slightly every few seconds when measuring, though a value not exceeding 3000 NTU is deemed favorable [23]. However, for water PH values, the lowest pH measured is in the noon to evening according to Table 5 (between 12.30 pm to 3.25 pm) compared to Wong Jun Hong *et al.* [23] is higher in the evening. A logical explanation would be that this is due to the artificial nature of the stream.

Table 6
Comparison of temperature, turbidity value, and pH values

Temperature				
Wong Jun Hong et. al			*Norsuzila et.al*	
Time	Variation of temperature	*Max*	Variation of temperature	*Max*
Morning	*25.35*°C		24°C to over 28°C.	28.56°C
Noon to mid- afternoon	27°C	27.73 °C		
Turbidity (NTU)				
Noon to mid-afternoon	2596.45	2596.45	2154.65-2375.65	2375.65
PH				
Morning	3.52		8.43	8.43
Evening	3.58		8.19	

4. Conclusion

The system has been devised to develop a low-cost system that connects the sensor system to the IoT that can be used to monitor real-time quality and act as an early warning system. Based on the results, the temperature condition affects the turbidity and pH of the water. It can be concluded that the temperature is directly proportional to the turbidity. Meanwhile, the pH decreases as the temperature rises. These findings indicate that the river is in good condition as the values of the parameters obtained are within the range. The system has proven its reliability, and data can be monitored on the phone and used for future monitoring and analyses.

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