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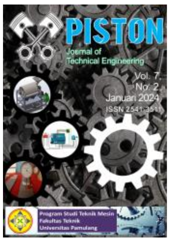

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LoRa-based IoT Device for Water Quality Monitoring (Case Study: Lake Toba)

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Abstract: Lake Toba, the largest lake in Indonesia, faces water pollution problems due to many sources of household waste, fertilizer waste from rice fields, and fish feed waste. Therefore, a water quality monitoring system is needed to warn the public and visitors early before they carry out recreational activities or use water from the lake. This research aims to build a system that can monitor the water quality of Lake Toba in real-time using LoRa technology, as well as analyze the water quality of Lake Toba with the parameters pH, dissolved oxygen, temperature, and turbidity. As a result, we created a water quality monitoring system and obtained water quality analysis results from 3 locations that are always busy with tourists. The results of measurements at Pantai Pasir Putih received a temperature range of 25.5°C to 28.5°C, turbidity ranged from 4.1 to 5.5 NTU; pH levels varied between 6.8 to 7.2, dissolved oxygen levels ranged from 8 .0 mg/L to 9.0 mg/ L. The results of measurements at Siregar Aek Nalas recorded temperatures ranging from 25°C to 28°C, turbidity levels of approximately 11.49 NTU and 14.65 NTU, pH levels fluctuating between 9 and 11, dissolved oxygen levels ranging from 29 mg/L to 32 mg/L. The temperature obtained for Pantai Lumban Bulbul was 25°C, turbidity ranged from 0.62 NTU to 2.60 NTU, the pH level was also consistently measured at 8, and dissolved oxygen levels were recorded at 9-10 mg/L.

Keywords: IoT; Wireless Sensor Network; LoRa; RSSI; SNR.

Abstrak: *Danau Toba, danau terbesar di Indonesia, menghadapi masalah pencemaran air akibat banyaknya sumber limbah rumah tangga, limbah pupuk dari sawah, dan limbah pakan ikan. Oleh karena itu, diperlukan sistem pemantauan kualitas air untuk memberi peringatan kepada masyarakat dan pengunjung sebelum mereka melakukan aktivitas rekreasi atau menggunakan air dari danau. Penelitian ini bertujuan untuk membangun sistem yang dapat memantau kualitas air Danau Toba secara real-time menggunakan teknologi LoRa, serta menganalisis kualitas air Danau Toba dengan parameter pH, oksigen terlarut, suhu, dan kekeruhan. Sebagai hasilnya, kami membuat sistem pemantauan kualitas air dan memperoleh hasil analisis kualitas air dari 3 lokasi yang selalu ramai dikunjungi wisatawan. Hasil pengukuran di Pantai Pasir Putih mendapatkan rentang suhu 25,5°C hingga 28,5°C, kekeruhan berkisar antara 4,1 hingga 5,5 NTU; tingkat pH bervariasi antara 6,8 hingga 7,2, tingkat oksigen terlarut berkisar antara 8,0 mg/L hingga 9,0 mg/L. Hasil pengukuran di Siregar Aek Nalas mencatat suhu berkisar antara 25°C hingga 28°C, tingkat kekeruhan sekitar 11,49 NTU dan 14,65 NTU, tingkat pH fluktuatif antara 9 dan 11, tingkat oksigen terlarut berkisar antara 29 mg/L hingga 32 mg/L. Suhu yang diperoleh untuk Pantai Lumban Bulbul adalah 25°C, kekeruhan berkisar antara 0,62 NTU hingga 2,60 NTU, tingkat pH juga konsisten diukur pada 8, dan tingkat oksigen terlarut dicatat pada 9-10 mg/L.*

Keywords*: IoT; Jaringan Sensor Nirkabel; LoRa; RSSI; SNR.*

INTRODUCTION

Lake Toba is the largest lake in Indonesia, located in a supervolcano's caldera. The lake is 100 kilometers long, 30 kilometers wide, and 508 meters (1,667 feet) deep. This lake is located in the middle of the northern island of Sumatra and has a surface height of around 900 meters (2,953 feet) [1], [2]. Lake Toba is currently a super-priority tourist destination, so many tourists visit it. However, there are weaknesses behind Lake Toba's beauty, especially regarding the water quality. Household, industrial, and agricultural waste are several sources of pollution affecting Lake Toba's water quality. This situation impacts the lake ecosystem, such as the high growth of water hyacinth, which also threatens life in the lake. Besides that, many local people use Lake Toba water for their daily needs and even consume it [1]–[3].

Figure 1. Lake Toba, located in North Sumatra (*https://id.m.wikipedia.org/wiki/Berkas:Map_of_Lake_Toba.jpg*)

The above information requires the construction of a water quality monitoring system. This research utilizes LoRa technology, divided into two parts: transmitter and receiver. These two nodes each have a LoRa microcontroller to transmit data via radio. Several sensors are configured on the receiver side with critical parameters such as water temperature, turbidity, dissolved oxygen content, and pH. This research is still in the prototype stage to be used as a final product that the community or local government can use.

Table 1. Wireless Technology [4]–[6]

Technology	Distance	Max. Rate	Power Consumption
Wifi	0-60 m	54 MB/s	High
Zegbee	0-1500 m	250 KB/s	Low
LoRa	1-15 km	600 KB/s	Low

LoRa (Long Range) is a wireless communication protocol for IoT and is capable of long-distance communication of approximately 15 km in remote areas [7], [8]. The ability to transmit over longer distances makes LoRa a suitable option for monitoring repetitive situations. Besides long distances, LoRa is designed to consume low power and does not use the internet network when transmitting data from transmitter to receiver. An internet connection is only needed if data needs to be accessed by certain websites or applications. Table 1 compares Lora with other wireless communication media, such as Wifi and Zegbee. These two technologies have a lower range and maximum rate. Meanwhile, regarding energy consumption, Zegbee and Lora are lower than WIFI. Subsequently, Lora is a suitable choice for monitoring the water quality of Lake Toba. Apart from that, researchers will also measure temperature, turbidity, pH, and dissolved oxygen levels. This parameter is essential as an initial source of information to determine the water quality of Lake Toba.

The primary objective of this research is to build a water quality monitoring system for Lake Toba using the Internet of Things (IoT) and LoRa (Long Range) technology and analyze water quality data using specific sensors. To achieve this goal, IoT technology has a very important role, where this concept allows an object to be connected to other objects via an internet connection. So that data collection and data analysis can be carried out efficiently and effectively. Basically, this concept consists of a transmitter and receiver, where several sensors will be installed on the transmitter side. The sensor will take surrounding data and convert the data into data bits that can be processed by a microcontroller, which in this research uses Arduino. Next, Arduino will process the commands programmed via the Arduino IDE software. With the help of the Arduino IDE, programs can be run on the microcontroller and connect various components such as drives, LCDs, and sensor modules.

STUDY LITERATURE

As can be seen in Fig. 2, which is a general overview of the LoRa network architecture design [9], [10], on the End Node or transmitter side, there are several sensors such as temperature, gas, pH, GPS, CCTV, and water meter sensors, including connected to the microcontroller and module[11], [12]. LoRa respectively. Meanwhile, the receiver or gateway side consists of a microcontroller component and a Lora module, which functions as a receiver. So that data can be sent, the Arduino on the transmitter will send data via the LoRa module using radio wave wireless communication with the LoRaWAN protocol. In this way, the data will reach the recipient. Furthermore, for monitoring needs, the receiver sends data via the internet using the ESP32 as a WIFI module.

Subsequently, users can monitor sensor data through a website or mobile application. Data will also be saved into the database.

Table 2. IoT Technology implementation in water quality monitoring

Ref	Topic	Wireless Technology	Parameter
[13]	IoT-based smart water quality monitoring system	Arduino ATMEGA328, WIFI	pH, turbidity, conductivity, carbon dioxide, humidity, temperature
[14]	IoT in Water Quality Monitoring—Are We Really Here?	WiFi, Bluetooth, or cellular	pH, temperature, and dissolved oxygen
[15]	Real-Time Internet of Things (IoT) Based Water Quality Management System	Arduino Uno	Temperature, pH, Turbidity
[16]	Water Quality Monitoring System Based On IoT	Wi-Fi module, MCU Arduino Atmega 328	pH, Turbidity, temperature, flow sensor

Table 2 shows the implementation of wireless technology in water quality monitoring. Various types of wireless technology such as WIFI, Bluetooth, cellular, and LoRa are used to obtain data from various water quality detection sensors such as pH, turbidity, conductivity, carbon dioxide, humidity, and temperature. This proves that wireless technology can be used to monitor water quality in real-time. Utilizing microcontroller technology such as Arduino, MCU, and Lora allows researchers to create end nodes that are connected to servers and can be monitored via applications.

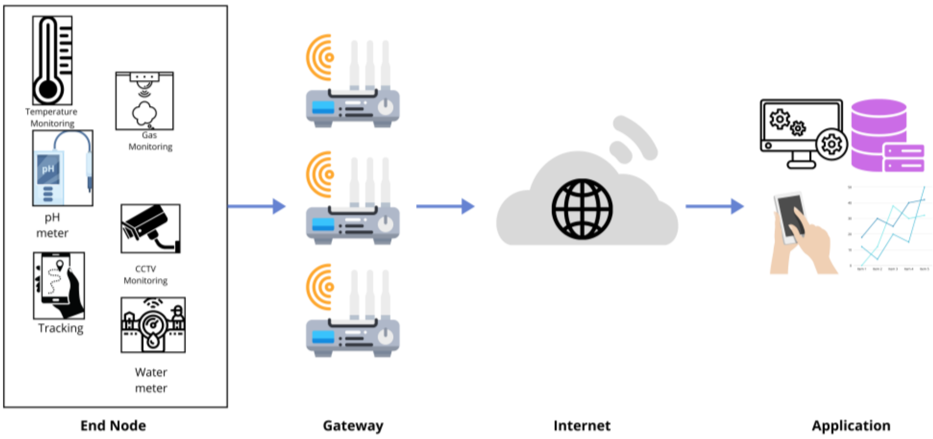

Fig. 2 Architecture of a LoRaWAN Network

Sensors such as pH, DO, temperature, and turbidity are essential in monitoring Lake Toba's air quality. These sensors provide important information about water quality parameters, making evaluating activities using Lake Toba easier. The LoRa module allows sending data from these sensors efficiently and accurately using radio frequencies. Applying LoRa technology to the Lake Toba water quality monitoring system provides excellent benefits: data collection efficiency, real-time monitoring, and energy savings. However, several aspects are challenging in implementing this technology and will affect signal strength, range optimization, and the quality of data arriving at the receiver. Environmental conditions are the main factors that can affect the signal, such as buildings, trees, building materials, slopes of land, vehicles, and all types of objects that become obstacles in a straight line from the transmitter to the receiver. Various methods are being researched to reduce these inefficiencies, such as antenna power, adjusted bandwidth, antenna height, most optimal SF and CR, and other methods that maximize data transmission.

METHODS AND IMPLEMENTATION

Fig. 3 shows the design model of this research. First, the sensors will detect the surrounding environment and translate it into data bits; the Arduino then processes the data and is ready to transmit it to the receiver using the Lora Module by utilizing the LoRaWAN protocol. The Lora receiver then receives the data, and the receiver then forwards the data to the database server using the HTTP protocol. Data stored in the database will be partially displayed for analysis purposes via a web display powered by Chart.js. Data shown for analytical needs, such as RSSI and SNR, will also be obtained from the receiver. Before carrying out water quality measurement tests, we first carry out a calibration. This test is carried out in the Bioprocess laboratory to ensure all sensors have accurate measurement values, as shown in Fig. 4 . Next is the LoRa calibration test. This test will be carried out by trying to send data or commands from the LoRa sender to the gateway. In this research, testing will be carried out at four different locations. The node will be fetched from the gateway. Then, an experiment will be carried out to display the data on the web. After everything is calibrated and tested individually, data integration testing, real-time data delivery, and display are carried out.

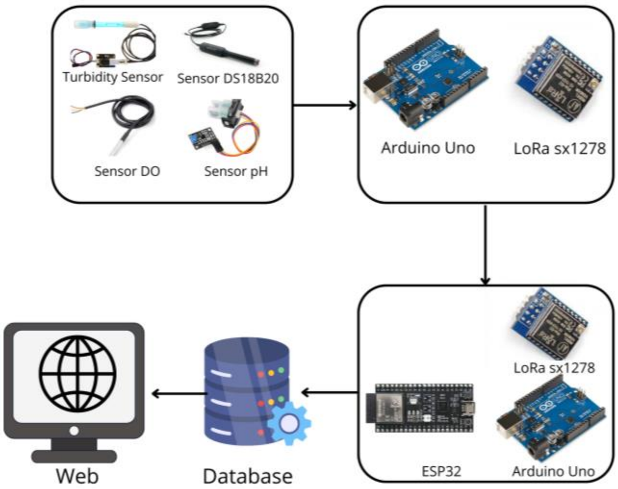

Fig. 3 Propose Design in Lora Network

Measurements were carried out at three strategic points busy with tourists: Pasir Putih, Siregar Aek Nalas, and Pantai Lumban Bulbul. The transmitter uses a box-shaped styrofoam box to avoid splashes of lake water. We placed this node right above the surface of the lake water, where it can still be reached. Meanwhile, we put the receiver on land around the coast at an estimated distance of 100 m. For data retrieval purposes, data transmission is set every 1 minute and measured for ± 1 hour. Data is collected in the database we built to carry out further analysis.

Fig. 4 is the implementation of the prototype transmitter that has been prepared. The system built consists of one node. The main components are Arduino Uno and LoRaSX1278. Several sensors are used to send data to the database and displayed on the website, such as pH Sensor, DO Sensor, DS18B20 sensor, and Turbidity Sensor. Meanwhile, the supporting components or tools are the Arduino Uno microcontroller board based on the Microchip ATmega328P microcontroller and the ESP32 microcontroller, which can function as the system's brain. A pH sensor measures a solution's acidity or basicity (pH) level. The DS18B20 sensor can monitor water temperature by continuously measuring water temperature, providing accurate temperature data, and helping to maintain water temperature within the desired range. Turbidity sensors in water measure the level of turbidity or clarity of water. The DO sensor measures the amount of dissolved oxygen in water. Meanwhile, the prototype receiver's role is to receive data sent by the transmitter. The prototype implementation acts as a receiver consisting of components such as ESP32 and LoRaSX1278. Meanwhile, for analysis, we compare the measurement data with the standards of REGULATION OF THE MINISTER OF HEALTH OF THE REPUBLIC OF INDONESIA NUMBER 32 OF 2017 [17].

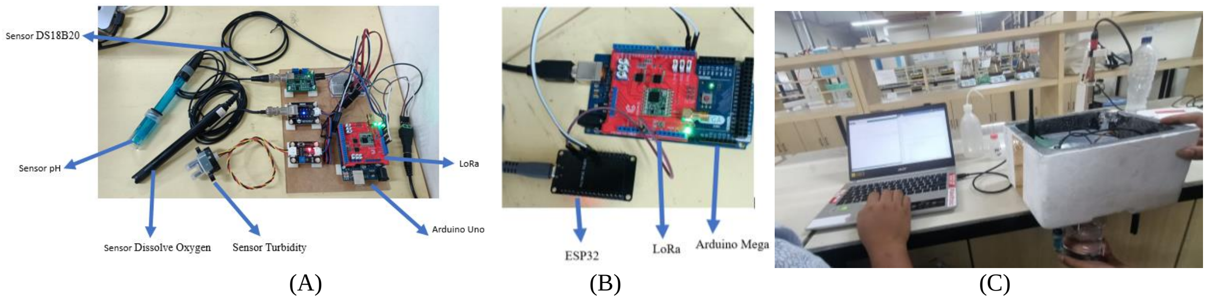

Fig. 4. Implementation of A) Transmitter, B) Receiver Node and C) Calibration Process of Sensors

RESULT AND DISCUSSION

A. Lake Toba Water Quality Monitoring Test at Pantai Pasir Putih

The first location studied was Pantai Pasir Putih. From the results of water quality measurements, it was found that the water temperature ranged from 25.5°C to 28.5°C. This temperature is still acceptable for sanitation and hygiene purposes, which can be used to maintain personal hygiene such as bathing and brushing teeth, as well as for washing food, eating utensils, and clothing. Apart from that, water for hygiene and sanitation purposes can be used as raw drinking water. Meanwhile, water turbidity ranges from 4.1 to 5.5 NTU, still below the standard threshold of 25 NTU. The pH level varies from 6.8 to 7.2, in line with the Environmental Health Quality Standards for Water Media for Sanitation Hygiene Purposes, namely 6.5 to 8.5 [17]. In addition, dissolved oxygen levels are between 8.0 mg/L and 9.0 mg/L, within the range of Environmental Health Quality Standards for Public Bath water media, which is 6.5 mg/L. This indicates that dissolved oxygen levels are lower than standard, which causes an unpleasant odor due to anaerobic degradation that may occur and will also affect the process of living creatures in the lake absorbing food.

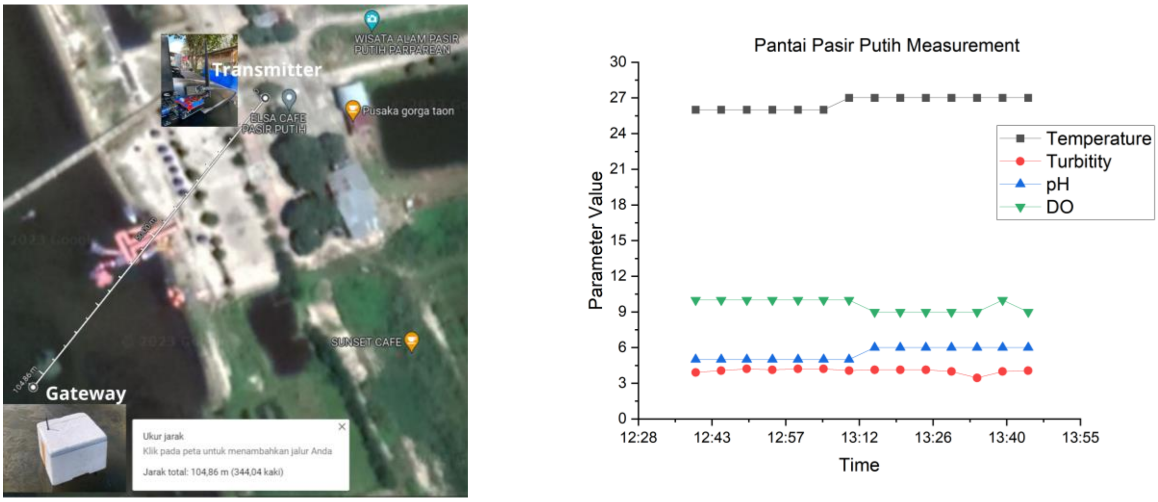

Fig. 5 Measurement of the water quality in Pantai Pasir Putih

B. Lake Toba Water Quality Monitoring Test at Siregar Aek Nalas

The second measurement location is Siregar Aek Nalas, as shown in Figure 6. The recorded temperature range, 25°C to 28°C, is within the limits of the Environmental Health Quality Standards for Water media for Sanitation Hygiene Purposes, namely 15-350C. Meanwhile, the turbidity level varies between 11.49 NTU to 14.65 NTU, indicating that this value is still within the threshold limit for Environmental Health Quality Standards for Water media for Sanitation Hygiene Purposes below 25 NTU. Meanwhile, pH levels fluctuated between 9 and 11, with an anomaly at 12:05, where the pH dropped to 9. This anomaly is of particular concern because it deviates from the generally accepted pH range of 6.5 to 8.5 for Quality Standards. These findings require further investigation regarding the cause of the increase in air pH, which indicates the presence of high pollution in the air. Likewise, dissolved oxygen levels, ranging from 29 mg/L to 32 mg/L, are slightly higher than existing quality standards. This indicates that the oxygen supply is significantly reduced, which will affect the lake ecosystem.

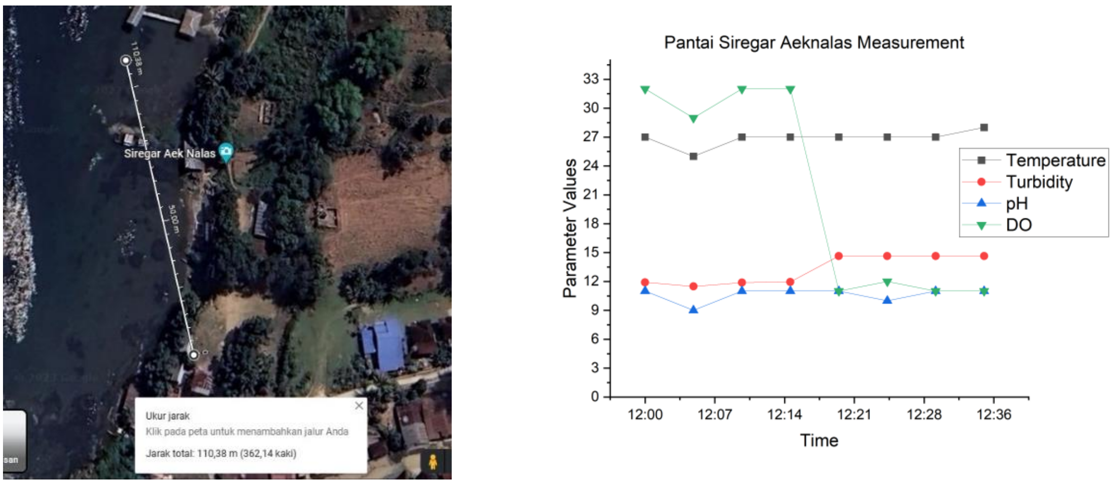

Fig. 6 Measurement of the water quality in Siregar Aek Nalas

C. Lake Toba Water Quality Monitoring Test at Pantai Lumban Bulbul

The subsequent measurement was carried out at Bulbul Beach, as shown in Figure 7 below. It is known that throughout data collection, the temperature obtained was consistently at 25 C. This value is within the quality standard. This shows a thermal environment conducive to the lake's aquatic ecosystem. Likewise, the turbidity values obtained range from 0.62 NTU to 2.60 NTU; this indicates that the water around this location is still of good quality because the matter is below the quality standard, namely 25 NTU. The pH level is also consistently measured at 8, within the standard pH range of 6.5 to 8.5 for sanitation hygiene purposes. This indicates the range is still within the Chemical Parameters in the Environmental Health Quality Standards for Water Media for Sanitation and Hygiene Purposes. Unfortunately, dissolved oxygen levels were consistently recorded at 9-10 mg/L, exceeding the quality standard threshold of 6.5. This value indicates low oxygen levels in the lake water, especially in the Pantai Lumban Bulbul area.

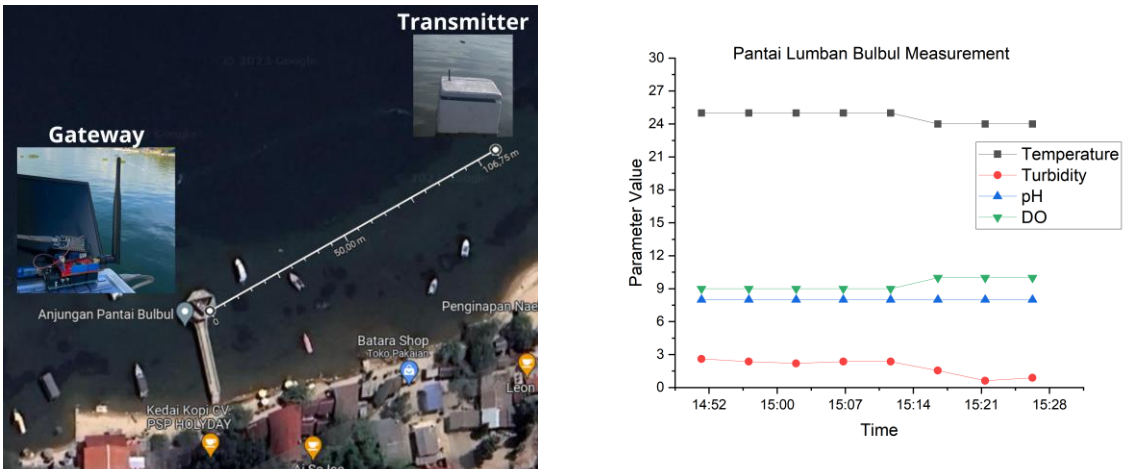

Fig. 7 Measurement of the water quality in Pantai Lumban Bulbul

This web appearance design section explains the web design that will be built as shown in the Fig.8. This web display is used to determine the results of the tested parameters. The following are the main page display designs of the web system being built.

Fig. 8 Website for monitoring the quality of Lake Toba's Water

CONCLUSIONS

We have succeeded in building a prototype for monitoring Lake Toba water quality using LoRa Technology using temperature, DO, pH, and turbidity sensors. The results of measurements at Pantai Pasir Putih obtained a temperature range of 25.5°C to 28.5°C, turbidity ranged from 4.1 to 5.5 NTU, pH levels varied between 6.8 to 7.2, dissolved oxygen levels ranged from 8.0 mg/L to 9.0 mg/ L. Measurement results at Siregar Aek Nalas recorded temperatures ranging from 25°C to 28°C, turbidity levels of approximately 11.49 NTU and 14.65 NTU, pH levels fluctuating between 9 to 11, dissolved oxygen levels range from 29 mg/L to 32mg/L. The temperature obtained by Pantai Lumban Bulbul was 25°C, turbidity ranged from 0.62 NTU to 2.60 NTU, pH was also consistently measured at 8, and dissolved oxygen levels were recorded at 9-10 mg/L. When compared with the REGULATION OF THE MINISTER OF HEALTH OF THE REPUBLIC OF INDONESIA NUMBER 32 OF

2017, Dissolved oxygen levels and lake water pH exceed the threshold limit; this is a severe problem that the community and government must immediately address. In the future, this research will be developed with a centralized receiving system so that many nodes can be placed in specific locations around Lake Toba. This can also be a reference for local governments to monitor the condition of Lake Toba.

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