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Implementation of Turbidity Sensor Based on IoT for Measuring Seawater Turbidity Levels in Gorontalo

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Abstract: Turbidity is the condition of water that is not clear due to suspended particles, such as mud, clay, organic matter, and microorganisms. This research aims to implement an Internet of Things (IoT)- based turbidity sensor to measure seawater turbidity levels in Gorontalo. The IoT-based turbidity sensor system was developed using the SEN-0175 turbidity sensor integrated with an ESP32 microcontroller. The Blynk application serves as a supporting platform for implementing IoT connected to a smartphone. Measurements of seawater turbidity were conducted in three locations in Gorontalo. The result for the first location is an area without residential areas, producing an average turbidity value of 16.5 NTU; the second location is a residential area with several food stalls, producing an average turbidity value of 24.99 NTU; and the third location is a culinary tourism area visited by many tourists, producing an average turbidity value of 50.56 NTU. These results show that the increasing number of human activities in coastal areas has the potential to pollute seawater. Excessive seawater pollution will increase seawater turbidity. Turbidity values exceeding the established seawater quality standards are unsuitable for Marine Tourism and disrupt marine biota; therefore, turbidity concentrations should be no more than 5 NTU. An IoT-based turbidity sensor is suitable for low-cost, real-time monitoring of seawater turbidity in Gorontalo, offering high precision, simple fabrication, and real-time operation.

Keywords: Internet of Things (IoT); Seawater; Sensor; Turbidity.

Introduction

Gorontalo is one of Indonesia's coastal regions with abundant water resources, including rivers, lakes, and the sea, directly connected to Tomini Bay [1][2]. However, in recent years, water levels in several areas have shown high levels of turbidity, particularly during the rainy season. Runoff from river basins, land erosion, agricultural activities, and coastal development are the main factors contributing to increased sediment particles carried into the ocean. This situation raises concerns because water quality significantly impacts the ecosystem and the lives of coastal communities [3]-[5].

Turbidity is the condition of water that is not clear due to suspended particles, such as mud, clay, organic matter, and microorganisms. Several factors cause turbidity, including soil erosion carried by river flows, heavy rainfall that increases surface runoff, and residential activities that generate domestic waste [6][7]. Scientifically, turbidity is measured in NTU (Nephelometric Turbidity Units) units, based on the principle of light scattering [8]. The higher the particle concentration in the water, the greater the turbidity. Turbidity not only affects the physical appearance of water but can also be an indicator of pollution or disturbances in the quality of the aquatic environment [9][10].

Maintaining seawater turbidity levels is crucial because it directly impacts ecosystem balance. Excessively turbid seawater can impede sunlight penetration, which phytoplankton and coral reefs need for photosynthesis. Consequently, the marine food chain can be disrupted, and fisheries productivity can decline. Furthermore, marine tourism and marine life can be impacted if water quality declines. Therefore, turbidity control is a crucial component of coastal environmental conservation and sustainable marine resource management [11]-[13].

Along with technological developments, seawater turbidity monitoring solutions can be implemented using a sensor system based on the Internet of Things (IoT) [14][15]. Previous research has developed a turbidity sensor using an Arduino to monitor seawater turbidity in maintaining coral reef ecosystems using the fuzzy logic method. This design was developed by determining the sensor error value [16]-[18]. The creation of a water turbidity measuring instrument using an LDR sensor and water quality monitoring using a nephelometric turbidity sensor based on Raspberry PI 3. This research was conducted to determine the relationship between output voltage and turbidity, as well as to determine sensor error [19][20]. Other research is developing a water quality detector using a turbidity sensor and an Arduino microcontroller as a seawater turbidity control system [21][22]. Some weaknesses of previous researchers include a lack of real-time IoT integration, reliance on complex systems, and limited field testing in seawater environments.

Based on the description above, it is necessary to design a turbidity sensor system based on IoT with the novelty of implementing a simple, real-time, low-cost IoT turbidity monitoring system applied directly to seawaters in Gorontalo. This system is expected to be connected to a microcontroller and a communication network to send data in real time to a server or a monitoring platform via a smartphone. to detect increases in turbidity early. With the turbidity sensor system based on IoT, monitoring seawater

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quality becomes more effective, efficient, low-cost, and accurate, enabling rapid decision-making in maintaining the sustainability of marine waters in Gorontalo.

Research Methods

The IoT-based turbidity sensor system was developed using the SEN-0175 turbidity sensor integrated with an ESP32 microcontroller. The SEN-0175 turbidity sensor measures seawater turbidity, while the ESP32 serves as the system's control center, or brain. In this study, the Blynk application is used as a supporting platform for the implementation of the IoT, which allows the microcontroller hardware to be connected to a smartphone in real-time via the internet. The system design is shown in Figure 1. The turbidity sensor was calibrated by comparing its measurements with a standard instrument using a turbidity meter to approximate the actual value, with an error rate of <5%. Measurements were made by directly immersing the sensor in a seawater sample. The results were then processed using Microsoft Excel to display the seawater turbidity level. Measurements of seawater turbidity were conducted in three locations, each with five sampling points. The first location for measuring seawater turbidity levels using an IoT-based turbidity sensor was in relatively clean seawater, with no residential areas, along the coast of Kurenai Beach, Gorontalo City. The second location for measuring seawater turbidity levels was in seawater, where there were food stalls and residential areas, located in the Tangga 2000 culinary area of Gorontalo City. The third location is in the sea, at Tamendao Beach in Gorontalo City, where a culinary area is located.

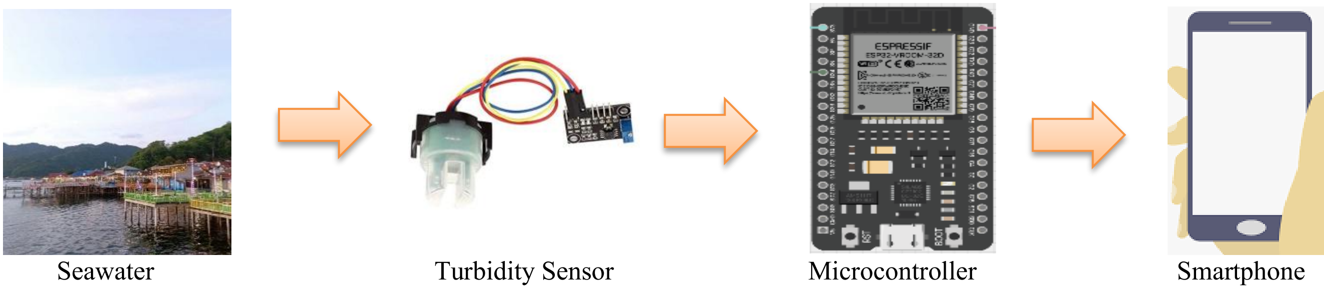

Figure 1. Schematic of seawater turbidity measurement research based on IoT

Results and Discussion

First Location

The first location for measuring seawater turbidity using an IoT-based turbidity sensor was in relatively clean waters, free of residential areas, along the coast of Kurenai Beach in Gorontalo City. Five samples were taken from different locations (A1, A2, A3, A4, and A5). The measurement results are shown in Figure 2.

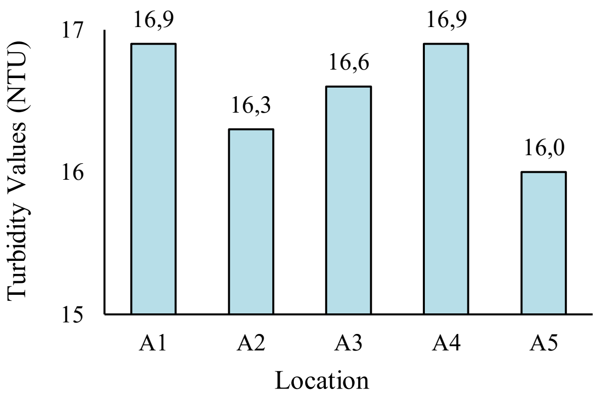

Figure 2. Turbidity value at the first location

The results of seawater turbidity measurements at the first location in Figure 2 show relatively similar turbidity values, ranging from 16 to 16.9 NTU. The lowest value was recorded at A5 with 16 NTU, while the highest value of 16.9 NTU was found at A1 and A4. The stability of the NTU values indicates that the seawater conditions at the first location are slightly turbid, with a turbidity level of < 25 NTU [23][24]. This seawater turbidity value is still within acceptable levels for coastal tourism areas and is safe for recreational activities such as swimming, although it is not intended for drinking water. Minimal human activity, the absence of waterborne waste, and low sediment runoff are the main factors contributing to the low turbidity levels. The turbidity value obtained is similar to that reported by previous researchers, with processing of shrimp ponds resulting in a turbidity of 16.23 NTU [25]. This value still exceeds the seawater quality standards set for Marine Tourism and marine biota, with a maximum turbidity concentration of 5 NTU [25][26].

Second Location

The second location for measuring seawater turbidity using an IoT-based turbidity sensor was in seawater near a food stall and residential area, located in the Tangga 2000 culinary area in Gorontalo City. Five samples were taken from different locations (B1, B2, B3, B4, and B5).

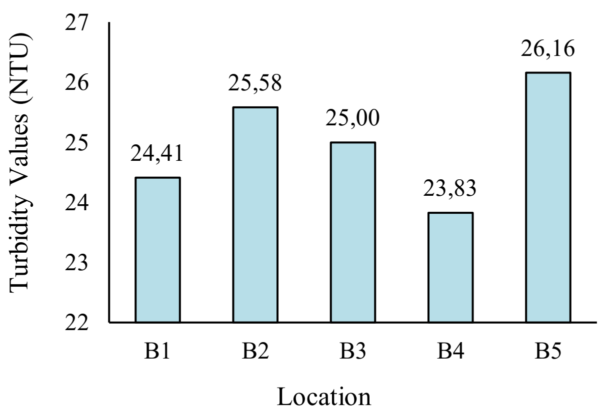

Figure 3. Turbidity value at the second location

B1 represents the seawater location near a coffee stall, B2 represents the location near a residential area, B3 represents the seawater location near a restaurant, B4 represents a location without residential areas, and B5 represents the seawater location near a food stall and residential area. The measurement results are shown in Figure 3. Figure 3 shows the results of seawater turbidity measurements at the second location. The turbidity values obtained were in the range of 23.83–26.16 NTU. The lowest value was recorded at B4 at 23.83 NTU, while the highest was at B5 at 26.16 NTU. Locations B1 and B4 are classified as lightly turbid with turbidity levels < 25 NTU, while B2 and B5 exceed 25 NTU [23][24]. Differences in turbidity values between locations are influenced by human activities along the coast, such as residential areas, coffee shops, and restaurants, as well as wave-driven sand runoff. Restaurant activities in coastal areas can affect seawater turbidity by discharging liquid waste into the water. Disposal of liquid waste that can enter the water, such as used washing water containing food scraps, detergents, and organic particles. Food scraps will settle, and some float in the water [27]. This value exceeds the seawater quality standards set for Marine Tourism and marine biota, with a maximum turbidity concentration of 5 NTU [25][26].

Furthermore, locations near residential areas tend to exhibit higher turbidity values due to the potential presence of suspended particles from domestic waste and coastal activities. Visually, the seawater in this area still appears relatively clear, but NTU values exceeding 25 NTU indicate that the water is not considered very clear. This value is still considered acceptable for coastal waters for tourism, but is unsuitable for drinking without further treatment.

Third Location

The third location for measuring seawater turbidity using an IoT-based turbidity sensor is in seawater near a culinary area at Tamendao Beach, Gorontalo City. This area is bustling and frequently visited by tourists. Five samples were taken from different locations (C1, C2, C3, C4, and C5). C1 and C2 are locations where cafes are located in the seawater, C3 is a location where restaurants are located in the seawater, C4 is a location where mini cafes are located in the seawater, and C5 is a location where residential areas are located in the seawater.

The results in Figure 4 show seawater turbidity measurements at the third location. This image shows high turbidity values, ranging from 49.18 to 52.06 NTU. The highest value was recorded at C3 (52.06 NTU), while the lowest was at C5 (49.18 NTU). These high turbidity values indicate that the seawater at this location contains a large amount of suspended particles. This may be caused by dense human activity, such as restaurants, cafes, residential areas, as well as sediment from waves and coastal activities. Restaurant activities in coastal areas can affect seawater turbidity by producing liquid and solid waste that enters the waters. Liquid waste that can enter the waters includes used washing water containing food scraps, detergents, and organic particles. Food scraps will settle, and some will float. Solid waste that can enter the waters includes plastic, tissue, and beverage dregs [27]. This value exceeds the seawater quality standards set for marine tourism and marine biota, with a maximum turbidity concentration of 5 NTU [25][26].

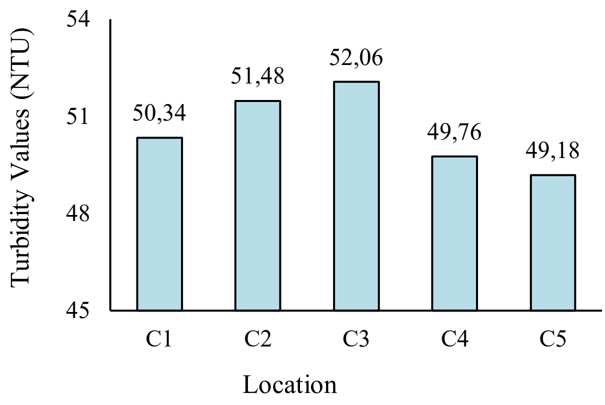

Figure 4. Turbidity value at the third location

The high seawater turbidity at this location is considered murky, making it less than ideal for water-based tourism activities such as swimming. This condition also indicates the potential for seawater pollution, which requires attention in coastal environmental management. A comparison of seawater turbidity measurements in Gorontalo using an IoT-based turbidity sensor at the first, second, and third locations is shown in Table 1.

Table 1. Comparison of Turbidity Values at Each Location

Sample	Turbidity Values (NTU)		
	1st Location	2nd Location	3rd Location
1	16.9	24.41	50.34
2	16.3	25.58	51.48
3	16.6	25.00	52.06
4	16.9	23.83	49.76
5	16.0	26.16	49.18
Average	16.5	24.99	50.56

Based on Table 1, the comparison of turbidity values between the first, second, and third locations is shown. The first location is an area without residential areas, producing an average turbidity value of 16.5 NTU; the second location is a residential area with several food stalls, producing an average turbidity value of 24.99 NTU; and the third location is a culinary tourism area visited by many tourists, producing an average turbidity value of 50.56 NTU. These results show that the increasing number of human activities in coastal areas has the potential to pollute seawater. Excessive seawater pollution will increase seawater turbidity. Turbidity values that exceed the established seawater quality standards are not suitable for Marine Tourism and disrupt marine biota, namely, turbidity concentration values of no more than 5 NTU [25][26]. A turbidity sensor is suitable for measuring seawater turbidity levels in Gorontalo, offering low cost, real-time operation, high precision, and simple fabrication.

Conclusion

Measurements of seawater turbidity using an IoT-based turbidity sensor were conducted at three locations. The first location is an area without residential areas, producing an average turbidity value of 16.5 NTU; the second location is a residential area with several food stalls, producing an average turbidity value of 24.99 NTU; and the third location is a culinary tourism area visited by many tourists, producing an average turbidity value of 50.56 NTU. These results show that the increasing number of human activities in coastal areas has the potential to pollute seawater. Excessive seawater pollution will increase seawater turbidity. Turbidity values that exceed the established seawater quality standards are not suitable for Marine Tourism and disrupt marine biota, namely, turbidity concentration values of no more than 5 NTU. An IoT-based turbidity sensor is suitable for measuring seawater turbidity in Gorontalo, offering low cost, real-time operation, high precision, and simple fabrication. IoT-based monitoring systems can support coastal environmental protection, pollution monitoring, and sustainable marine tourism management. Suggestions for future research include integrating additional water quality parameters, such as pH, salinity, and temperature, or conducting long-term monitoring studies.

Author's Contributions

M. Yunus: Conceptualization, writing-original draft preparation, methodology, writing-review and editing.

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