REKAYASA
Journal of Science and Technology
https://journal.trunojoyo.ac.id/rekayasa

Rekayasa, 2024; 17(3): 361-371
ISSN: 0216-9495 (Print)
ISSN: 2502-5325 (Online)

Pond Water Quality Monitoring in Consumption Fish Farming Industry Based on Internet of Things

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DOI: https://doi.org/10.21107/rekayasa.v17i3.25428
Submitted April 17th 2024, Accepted December 4th 2024, Published December 27th 2024

Abstrak

Peningkatan jumlah penduduk Indonesia yang pesat menyebabkan permintaan akan protein hewani meningkat. Sebagai salah satu sumber protein hewani, ikan memiliki potensi yang sangat baik untuk dikembangkan di Indonesia. Namun, perhatian terhadap kualitas air yang merupakan kebutuhan dasar sering kali terabaikan. Sementara itu, peningkatan produksi ikan dapat dilakukan dengan menjaga kualitas air agar selalu dalam kondisi baik. Penelitian yang dilakukan ini bertujuan untuk memantau kualitas air secara berkelanjutan. Integrasi sistem pemantauan kualitas air menggunakan *Internet of Things* (IoT) menawarkan kemudahan dalam pemantauan secara *real-time* dan tidak harus hadir di lokasi. Parameter yang menentukan kualitas air ikan adalah pH, daya hantar listrik (EC), oksigen terlarut (DO), kekeruhan, dan suhu air. Data yang diperoleh kemudian ditampilkan pada *Dashboard Water Monitoring* dalam bentuk grafik, indikator, dan data mentah yang dapat diunduh oleh pengguna. Secara keseluruhan, sistem dapat mengukur, memantau secara real-time, dan menyimpan data hasil pengukuran kualitas kolam ikan air tawar pada smartphone/laptop. Sistem yang dikembangkan juga memberikan informasi apakah kualitas air dalam kondisi normal atau dalam kondisi kurang dan lebih dari ambang batas. Oleh karena itu, sistem yang dikembangkan ini membantu petani memantau kualitas kolam ikan mereka untuk meningkatkan produktivitas budidaya ikan.

Kata Kunci: kualitas air, *internet of things*, pemantauan, *real time*

Abstract

The rapid increase in population in Indonesia has increased the demand for animal protein. As a source of animal protein, fish has excellent potential to be developed in Indonesia. However, care for water quality, a basic need, is often ignored. Meanwhile, increasing fish production can be done by ensuring that water quality is always in good condition. This research conducted aims to monitor water quality continuously. Integrating water quality monitoring systems using the Internet of Things (IoT) offers convenience in real-time monitoring and does not have to be present on-site. The parameters determining fish water quality are pH, electrical conductivity (EC), dissolved oxygen (DO), turbidity, and water temperature. The data obtained is then displayed on the Water Monitoring dashboard as graphs, indicators, and raw data the user can download. Overall, the system can measure, monitor in real-time, and store data on the results of measuring the quality of freshwater fish ponds on smartphones/laptops. The developed system also provides information on whether the water quality is "normal" or in conditions less and more than the threshold. Therefore, the developed system helps farmers monitor the quality of their fish ponds to increase the productivity of fish farming.

Key words*: water quality, internet of things, monitoring, real time*

INTRODUCTION

Along with the increasing population of Indonesia, of course, the demand for animal protein will be even more significant (Saputri, 2020). Freshwater fish is a source of protein that is widely consumed by the community because it is relatively affordable. Increasing freshwater fish production can be done by feeding and maintaining good water quality. The quality of a water body is an essential requirement that can affect the survival, development, growth, and production levels of fish (Fauzia & Suseno, 2020).

On the other hand, boosting aquaculture production intensively and extensively using feed has an impact on reducing water quality. This leads to eutrophication, which can create conditions where aquaculture waters lack oxygen and increase toxic materials such as ammonia, which can cause regular mass mortality (Syamsunarno & Sunarno, 2016). This negatively impacts aquaculture owners, who must be prepared to monitor water conditions directly, which is not effective and efficient. Therefore, a tool is needed to provide real-time information on pond water quality.

One of the efforts to overcome the problems fish farmers face is utilizing the Internet of Things (IoT) for water quality monitoring in fish farming (Rohadi *et al.*, 2018). Until now, IoT technology has developed massively and has been applied in environmental monitoring. One example of IoT application in the field of environmental monitoring is for air pollution control with dangerous levels (Idrees *et al.*, 2018), air quality monitoring that can be monitored in real-time and connected to the government to determine policies (Montanaro *et al.*, 2022), to be combined with machine learning for further analysis and prediction (Almalawi *et al.*, 2022; Asha *et al.*, 2022; Hussain *et al.*, 2020; Senthilkumar *et al.*, 2020), disaster mitigation such as flooding by monitoring remotely via internet connection and providing early warning (Chaduvula *et al.*, 2023; Shah *et al.*, 2018; Zahir *et al.*, 2019), to be improved using computer vision (Arshad *et al.*, 2019) and applying wireless sensor networks to cover flood monitoring in a large area with several monitoring points (Mendoza-Cano *et al.,* 2021).

IoT applications are also applied to monitor potential forest fire points equipped with early warnings to anticipate larger fires (Basu *et al.*, 2018; Srividhya & Sankaranarayanan, 2020), integrated with machine learning (Dubey *et al.*, 2019; Grari *et al.*, 2022), combined with wireless sensor networks for more comprehensive coverage (Benzekri *et al.*, 2020), also applied for early detection of fires in urban centers (A. Sharma *et al.*, 2020), landslide detection with various techniques (Bagwari *et al.*, 2021; Karunarathne *et al.*, 2020; Thirugnanam *et al.*, 2022), integrated with cameras as the primary sensor (Aggarwal *et al.,* 2018), wireless sensor networks in a broader coverage (Hakim *et al.*, 2020), to be loaded in big-data as high-level analysis material (Lau *et al.,* 2023). Typhoons or climate change are monitored to study and anticipate potential negative consequences by integrating machine learning for prediction (Salam & Salam, 2020; Verma *et al.*, 2022; Wang *et al.,* 2021). Earthquake prediction is equipped with an early warning system (Alphonsa & Ravi, 2016; Pirmagomedov *et al.*, 2018; Saini *et al.*, 2022; Zambrano *et al.,* 2017) to apply deep learning (Abdalzaher *et al.,* 2021), crop monitoring on large land areas which is often expressed as smart farming or precision agriculture (Bauer & Aschenbruck, 2018; Jain & Kumar, 2020; Rajakumar *et al.,* 2018; Triantafyllou *et al.*, 2019), to combine with wireless sensor networks (Jawad *et al.,* 2017), monitoring renewable energy power harvesters in remote areas (Sharma *et a*l., 2020; Zeadally *et al.*, 2020), more specifically monitoring is focused on power harvesters with photovoltaic (Fedele *et al.,* 2018; Priharti *et al.*, 2019; Subrata *et al.*, 2022), and wind power (Ali *et al.*, 2022; Karad & Thakur, 2021), to be applied in water quality monitoring (Arafat *et al.*, 2020; Chen *et al.*, 2022; Danh *et al.,* 2020; Kaur *et al.*, 2023; Lakshmikantha *et al.,* 2021; Nocheski & Naumoski, 2018; Pappu *et al.*, 2017; Pasika & Gandla, 2020; Ramya *et al.*, 2019; Udanor *et al.*, 2022).

IoT technology has been widely applied to monitor water parameters, whether it is used for consumption water sources, irrigation water sources, or water sources for fish farming. The application of IoT technology to measure water parameters varies depending on its functional purpose. What must be considered is what parameters will be monitored so that IoT can work efficiently, not wasting costs but increasing operational effectiveness to bring good economic benefits.

Researchers have made various efforts to implement IoT technology that functions as a water parameter monitor. Pasika and Gandla (Pasika & Gandla, 2020) developed a water quality monitoring device to ensure consumer safety. The developed device uses turbidity, pH, water level, ambient and humidity air temperature sensors displayed through the ThinkSpeak application. With a similar theme, Lakshmikantha et al. (Lakshmikantha *et al.*, 2021) monitored contamination and pollutants contained in drinking water. The system developed has a CO2 detection function and is equipped with an early warning system.

Meanwhile, Pappu *et al* (2017) used pH and TDS sensors to measure and predict freshwater quality by integrating M2M and K-Means clustering methods. However, these studies used laboratory-scale sensors where validation of sensor accuracy needs to be done and improved. Furthermore, using sensors limited to only two parameters to determine the water quality level is insufficient.

The IoT concept implemented in fish ponds generally aims to manage and monitor fish ponds in real time. Monitoring fish ponds in real-time allows fish pond workers not to be present on the spot (Hidayatullah *et al.,* 2018). This monitoring will increase efficiency and productivity, so it is necessary to integrate various tools in conventional ponds with IoT technology. In line with this integration goal, IoT-based tools have the opportunity to automate various fishery aids in real time. Therefore, this paper discusses monitoring fish pond water by utilizing IoT technology.

METHODS

Design of Proposed Method

The IoT-based fish pond quality monitoring device diagram has three layers: sensor, control, and output. The diagram of the designed device is shown in Figure 1. The sensor layer serves as the primary input to the developed tool. The sensor layer consists of five sensors to measure the quality of freshwater fish ponds: pH, electrical conductivity (EC), dissolved oxygen (DO), turbidity, and water temperature. Data collection of all parameters is done in real-time, synchronously, and scheduled. The second layer is the control layer, consisting of a microcontroller as the central data processor. Inside the microcontroller board is an integrated circuit chip supported by an internet signal catcher, namely the ESP module. In this control layer, the work process occurs by receiving input signals from the Sensor Layer, which are then processed in the Control Layer. Then, the data is sent to the cloud using internet signals and to the output layer. The output layer is a viewer in the form of a website that can be accessed on a computer or smartphone device that has an internet connection. This output layer displays real-time data sensings from the pH, EC, DO, turbidity, and water temperature sensors. The output layer displays graphs, notifications, and raw data that can be downloaded.

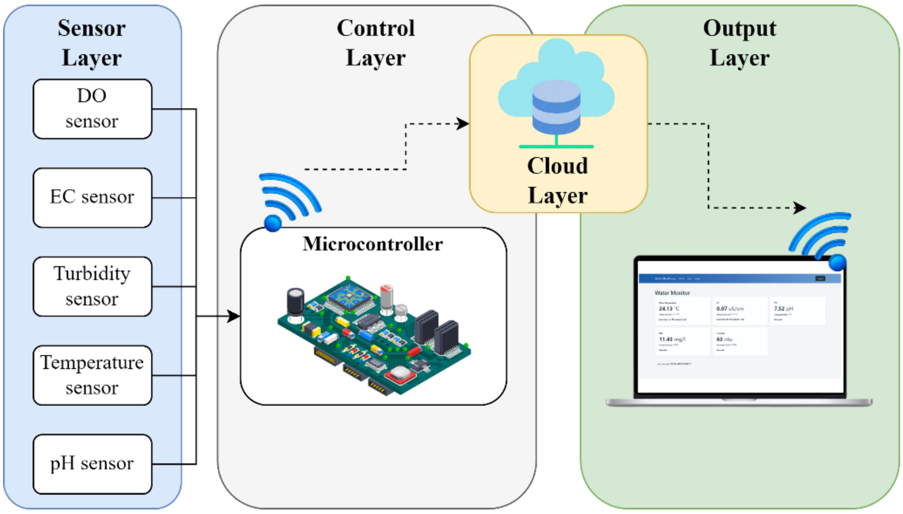


Figure 1. Diagram of IoT-based fish pond quality monitoring

Hardware Design

The hardware design can be seen in Figure 2. In addition to sensors to measure water quality parameters, the developed tool also has several components for data support. The components for data support are RTC to calculate time in real-time, and an SD card module to store water quality monitoring data to external storage.

Signal processing modules are used in the pH, EC, DO, and Turbidity sensors. The signal processing module provides a filter for each sensor probe's senses. The pH sensor is equipped with an MSP340 signal processing module, which is used to measure the acidity of the water. The EC sensor is equipped with a SEN0244 signal processing module, which is used to measure the electrical conductivity and calculate the water's total dissolved solids (TDS). The DO sensor is equipped with the SEN0237 signal processing module to measure the amount of dissolved oxygen content in a liquid. The water turbidity sensor is equipped with the SEN0189 signal processing module to measure water turbidity. The water temperature sensor uses no additional modules to measure the water temperature. All electric components used in this device are integrated into a single embedded system. A special circuit board was designed to accommodate a compact and robust system. The design of the circuit board developed for measuring the water quality of farmed fish ponds is shown in Figure 3.

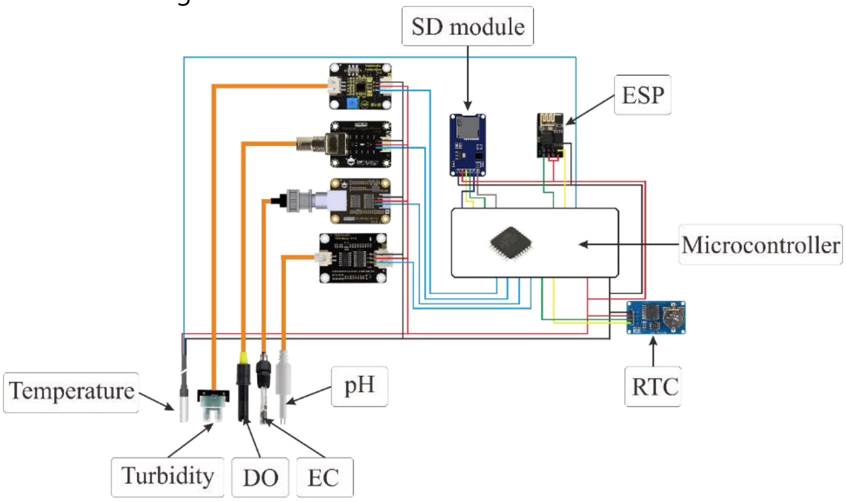


Figure 2. Wiring diagram of the proposed device

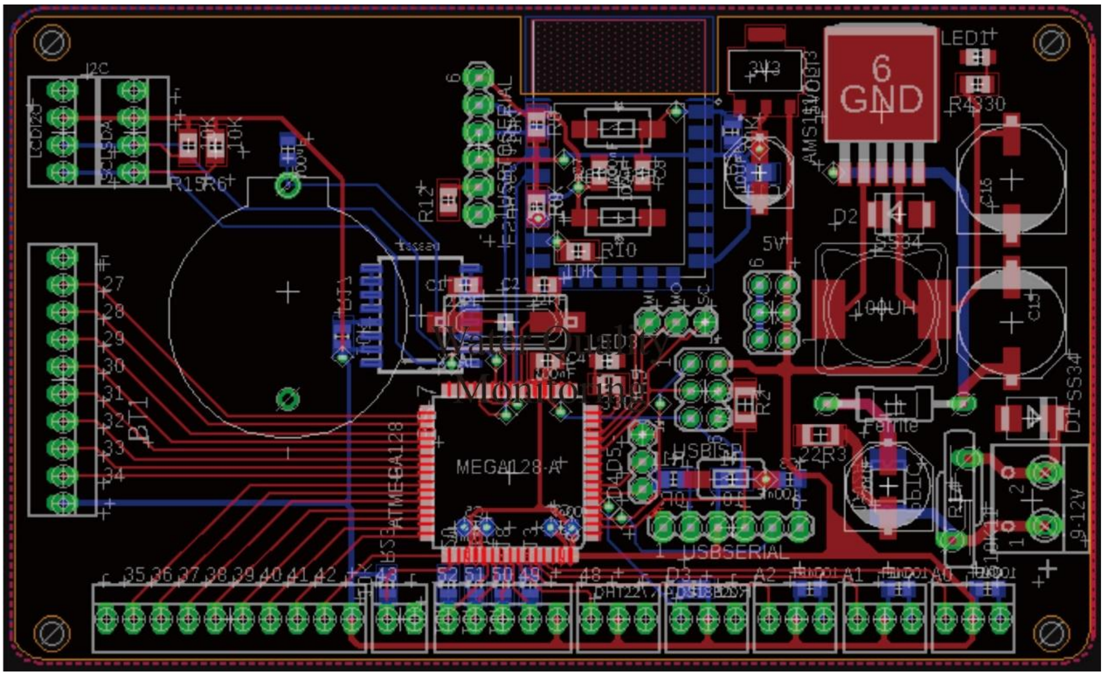


Figure 3. Double-layer circuit board design

A water quality measuring circuit board is the central controller in aquaculture fish ponds' water quality measuring device. This circuit board measures 100mm x 67 mm, with a power consumption of 5 watts. The control system of this water quality meter is supported on an integrated circuit based on ATMega 128. This circuit board has a speed of 16 MHz and has a layer of 2 layers. This circuit board is equipped with Internet of Things (IoT) technology with an ESP8266 chip with 802.11 b/g/n protocol (HT20) and a frequency of 2400 MHz ~ 2483.5 MHz.

RESULT AND DISCUSSION

After going through various stages ranging from design to hardware manufacturing, a device used to detect pond water quality has been completed and implemented in an actual fish farming pond. The system was developed at the Yogyakarta Aquaculture Technology Development Center (BPPTB), as shown in Figure 4. This water quality detector is specialized to measure the quality of freshwater aquaculture. The quality of the freshwater pond is determined through five parameters: water pH sensor with signal processing module MSP340, TDS sensor with signal processing module SEN0244, and DO sensor with signal processing module. SEN0237-A, water turbidity sensor with signal processing module SEN0189, and water temperature sensor. Data from the sensors is sent and processed by the microcontroller embedded in the embedded system. The internet network is used as a telemetry medium to transmit water quality data, and it is connected to the Water Monitor platform as an interface medium.

Figure 4. Implementation at BPPTB Yogyakarta

Measurement of Water Quality Parameters

Sensor testing was carried out in the freshwater fish pond of the BPTPB Yogyakarta for 34 hours. Water quality requirements from BPTPB Yogyakarta can be seen in Table 1. These water quality requirements are crucial because they are used to determine the measured water quality. The water quality requirements used are general. There are variations in the range of parameter values required for each type of fish, but general water quality requirements based on BPTPB DIY were used in this study. The results of the tests conducted for about 34 hours are displayed in graphical form.

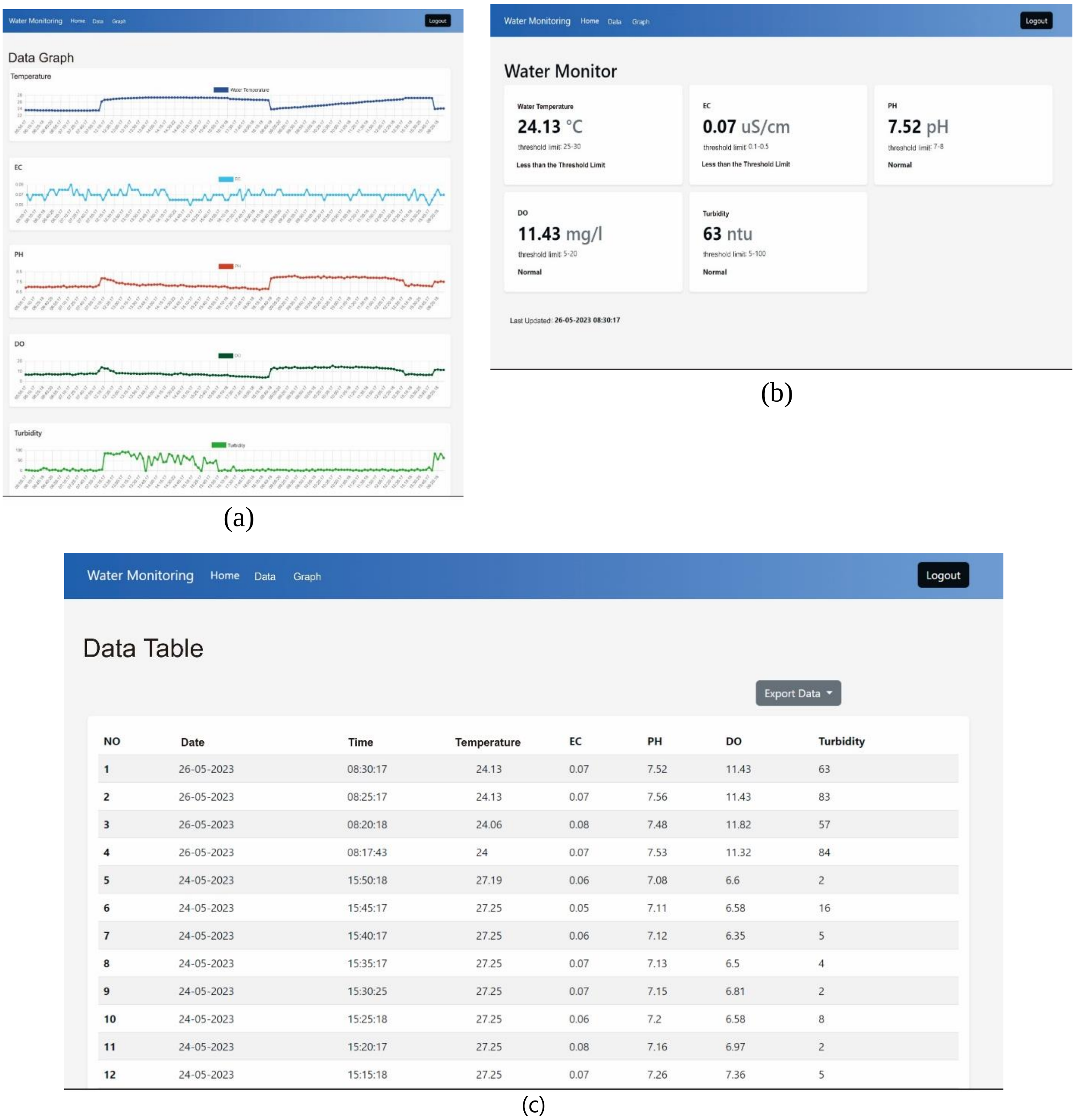
Table 1. Water quality requirements from BPTPB Yogyakarta

Parameter	Range	Optimum
Water temperature℃	25 – 30	25 – 30
EC (uS/cm)	0.1 – 0.5	< 0.1 – 0.5
pH (pH)	7 - 8	7 – 8
DO (ntu)	0.1 - 20	> 5 - 20
Turbidity (mg/l)	0 - 100	0 – 100

Real-time Monitoring Dashboard

The measurement results of the sensors are then displayed in real-time on the monitoring dashboard that has been developed. The dashboard display consists of a graph that displays the value of the sensor measurement results in real-time, as shown in Figure 5. The graph displaying the value of the sensor measurement results will update automatically every 5 minutes according to the parameter measurement sampling settings embedded in the microcontroller. This graph viewer can display the results of sensor measurement values up to 100 times. If the value of the sensor measurement results is displayed more than 100 times, the graph will delete the oldest measurement result value point.

As seen in Figure 5a, which shows a graph of the measurement values of all sensors, the maximum temperature measurement results reached 27.25 °C, the maximum EC value of 0.09 uS/cm, the maximum pH value of 7.56, the maximum DO value of 15 ntu, the maximum turbidity value of 92 mg/l. The measurement of water quality parameters using the developed tool has also been compared with standard equipment from BPTPB DIY. The measurement comparison results of the two tools show an average similarity of up to 99.8%.



NO	Date	Time	Temperature	EC	PH	DO	Turbidity
1	26-05-2023	08:30:17	24.13	0.07	7.52	11.43	63
2	26-05-2023	08:25:17	24.13	0.07	7.56	11.43	83
3	26-05-2023	08:20:18	24.06	0.08	7.48	11.82	57
4	26-05-2023	08:17:43	24	0.07	7.53	11.32	84
5	24-05-2023	15:50:18	27.19	0.06	7.08	6.6	2
6	24-05-2023	15:45:17	27.25	0.05	7.11	6.58	16
7	24-05-2023	15:40:17	27.25	0.06	7.12	6.35	5
8	24-05-2023	15:35:17	27.25	0.07	7.13	6.5	4
9	24-05-2023	15:30:25	27.25	0.07	7.15	6.81	2
10	24-05-2023	15:25:18	27.25	0.06	7.2	6.58	8
11	24-05-2023	15:20:17	27.25	0.08	7.16	6.97	2
12	24-05-2023	15:15:18	27.25	0.07	7.26	7.36	5

Figure 5. (a) Graph of sensing results; (b) Water quality indicator in the monitoring dashboard; (c) Detailed downloadable sensing data

The second dashboard display shows the sensing results indicator in Figure 5b. This display has a range of water quality requirements adjusted to the standards of BPTPB Yogyakarta, as shown in Table 1. If the sensor measurement results value is outside the range of requirements, a statement will be displayed that the parameter value is less than or more than the required range. A concrete example is shown in Figure 6, which displays the sensing value at 08.30 A.M. It can be seen that the water temperature is 24.14 ℃, which means that the value is outside the range of water quality requirements (25-30 ℃). Therefore, an indicator indicates that the measured water temperature value is less than the threshold limit. The third dashboard view displays detailed data on the measurement values of all sensors, as shown in Figure 5c. The data is stored in the cloud and displayed on the dashboard with the sensors' time and date of water quality measurements. The data can then be uploaded into a CSV document via the "Export Data" menu. This allows stakeholders to conduct further evaluation and analysis using the downloaded data. The sensor measurement data obtained is compared with the industrial sensor measurement data owned by BPTPB. The measurement parameters compared are Temperature, pH, DO, and Turbidity. Table 2 compares measurements from the developed tool with industrial measuring tools.

Table 2. Comparison between proposed and industrial sensing result

Temperature (℃)			**pH (pH)**			**DO (ntu)**			**Turbidity (mg/l)**		
Proposed	Industrial	Error (%)	Proposed	Industrial	Error (%)	Proposed	Industrial	Error (%)	Proposed	Industrial	Error (%)
28,0	27,7	1,08	7,51	7,52	0,13	6,97	6,99	0,29	57,21	57,32	0,19
28,4	28,3	0,35	7,52	7,54	0,27	6,73	6,75	0,30	56,32	56,56	0,42
28,6	28,3	1,06	7,42	7,45	0,40	6,35	6,37	0,31	57,45	57,65	0,35
29,2	28,8	1,39	7,53	7,56	0,40	6,36	6,37	0,16	57,88	57,98	0,17
30,7	30,2	1,66	7,44	7,45	0,13	6,47	6,49	0,31	60,31	60,54	0,38
31,1	30,9	0,65	7,18	7,21	0,42	6,61	6,64	0,45	61,32	61,65	0,54
31,9	31,1	2,57	7,2	7,23	0,41	6,89	6,93	0,58	61,56	61,7	0,23
32,3	32,0	0,94	7,34	7,35	0,14	7,54	7,59	0,66	61,78	61,88	0,16
32,4	32,1	0,93	7,56	7,57	0,13	7,32	7,35	0,41	62,43	62,6	0,27
32,6	32,5	0,31	7,32	7,33	0,14	7,32	7,36	0,54	62,34	62,5	0,26
Average		1,09	Average		0,26	Average		0,40	Average		0,30

CONCLUSIONS

Monitoring the quality of freshwater fish ponds can work well by measuring parameters such as temperature, pH, turbidity, DO, and EC using a Water Monitor as an interface with Microcontroller software. Data sensing is sent to the Water Monitor and successfully displayed in real-time in graphs and data block diagrams. The results of system sensing are in the form of conditions when normal, above and below the threshold. Overall, the system developed can measure and store data from the measurement of the quality of freshwater fish ponds so that farmers can take appropriate action if there are significant changes in water quality. Therefore, this tool can be implemented in freshwater fish ponds owned by farmers to increase the productivity of fish farming.

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