Engineering Innovations
ISSN: 2813-1002, Vol. 16, pp 97-105
doi:10.4028/p-5l14Yq

Submitted: 2025-02-05
Revised: 2025-04-22
Accepted: 2025-08-07
Online: 2026-01-07

Water Quality Monitoring Device: IoT-Based System for Aquaculture Applications

M. Rasyid Ridla[1,a], Haidar Ali[1,b], Nandang Mufti[1,2,c*], Saparullah[1,d], M. Tommy Hasan Abadi[1,e], Naufal Fiego Fadhlullah[1,f], Erma Surya Yuliana[1,g], Muladi[3,h], Yoyok Adisetio Laksono[1,i]

[1]Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang 5 Malang 65145, Indonesia

[2]Centre of Advance Materials for Renewable Energy, Universitas Negeri Malang, Jl. Semarang 5 Malang 65145, Indonesia

[3]Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Malang, Jl. Semarang 5 Malang 65145, Indonesia

[a]muhammad.rasyid.2203228@students.um.ac.id, [b]haidar.ali.2003228@students.um.ac.id, [c*]nandang.mufti.fmipa@um.ac.id, [d]saparullah.1903225@students.um.ac.id, [e]m.tommy.1303226@students.um.ac.id, [f]naufalfiego.1903226@students.um.ac.id, [g]erma.surya.2203228@students.um.ac.id, [h]muladi@um.ac.id, [i]yoyok.adisetio.fmipa@um.ac.id

[a*]Corresponding author: nandang.mufti.fmipa@um.ac.id

Keywords: water quality monitoring, system, IoT, water quality parameters, aquaculture.

Abstract. Rising demands for precise and efficient water quality monitoring have accelerated the adoption of IoT technologies, particularly in aquaculture environments. This article discusses the development of Internet of Things (IoT)-based water quality monitoring devices. This device enables real-time monitoring of water quality parameters, including temperature, total dissolved solids (TDS), electrical conductivity (EC), resistivity, and salinity. The device involves the use of several water-quality sensors connected to a microcontroller that serves as the central processing unit. Sensor data is transmitted wirelessly to a cloud platform for analysis. The results are then presented through a user-friendly visualization on a Human-Machine Interface (HMI) device or Android application. The main advantage of this device is its ability to provide real-time data that allows quick response to changes in water conditions. The system was tested on various water samples, demonstrating stable measurements when compared to the Hanna Instrument HI98194 standard device. Further calibration of the TDS sensor is necessary to improve the accuracy of Total Dissolved Solids (TDS), Electrical Conductivity (EC), resistivity, and salinity measurements.

Introduction

Poor water quality poses a serious challenge to both public consumption and industries such as aquaculture and manufacturing. Water quality must undergo rigorous testing to assess its suitability for public distribution by drinking water providers [1]. Water quality is a key factor in ensuring the success of aquaculture and fisheries businesses. Key water parameters-such as salinity, pH, temperature, dissolved oxygen, and total dissolved solids-must be carefully monitored to support optimal fish growth and health [2,3]. Poor water circulation in ponds-caused by leftover feed, metabolic waste, and limited water exchange-can disrupt water quality parameters such as dissolved oxygen levels, which in turn impacts fish growth [4].

The importance of monitoring water quality as a living medium for fish encourages the development of methods for monitoring pond water quality. Traditionally, water quality has been assessed through laboratory analysis, which involves sampling pond water and testing it in a controlled environment. Sensors have been introduced to monitor specific water parameters, although most are limited to measuring only one variable per sensor [5,6]. This approach is both inefficient and time consuming, limiting its practicality in real time aquaculture operations.

Many researchers have developed Internet of Things (IoT)-based systems to monitor water quality in aquaculture. This monitoring system was developed to monitor several parameters such as pH, temperature, salinity, electrical conductivity, dissolved solids, and dissolved oxygen levels[7]. The calibration process for the multi-sensor monitoring system is carried out using a comparison method with standardized devices, including pH sensors calibrated with buffer solutions and temperature sensors equipped with the HEL-711 RTD. The calibration process itself is carried out for 24 hours and then the results are analyzed so that small range differences are obtained. The minor discrepancies observed suggest that the developed system has achieved sufficient accuracy for practical implementation [8].

Sobri et al. (2021) have developed an IoT-based water quality monitoring system for real-time measurements using Total Dissolved Solids (TDS) sensors, pH sensors, and temperature sensors. The device measures parameters including temperature, pH, and salinity. Some of these values, such as salinity, are inferred through mathematical relationships from the TDS sensor readings [9]. Chuzaini (2022) has also developed IoT-based water quality monitoring which is used to measure temperature, pH, and TDS levels in water. Water sample measurements were carried out in rural areas, near the sea, and in industrial areas with high measurement accuracy[10]. The monitoring system that has been created by Adityas et al. (2021) can measure temperature, pH, salinity, and turbidity parameters. However, there are still shortcomings in the form of measurement results that are not clearly presented or easily interpretable by end users because the data on the website is only presented in graphical form, making it quite difficult for lay users to understand the water quality levels of the testing system[11].

Based on the explanation above, many water quality monitoring systems have been developed. However, there are constraints on the number of sensors, the lack of water quality parameters that can be measured, and the user interface design lacks interactivity and visual clarity, making it difficult for non-experts to interpret water quality data. In this research, an IoT-based water quality monitoring tool will be developed for real-time monitoring of water quality in aquaculture businesses. The components of this monitoring system consist of a microcontroller, TDS sensor, temperature sensor, and LCD touchscreen which are connected in a box enclosure. Arduino IDE is used for programming and Blynk used as more communicative user interface to display water quality monitoring results.

Research Method

The research begins with the design of both hardware and software components. The hardware includes a microcontroller, temperature sensor, TDS sensor, and a Human Machine Interface (HMI) device. The software is developed using Arduino Uno, MySQL, Node-RED, and Blynk. The system architecture of the proposed water quality monitoring device is illustrated in Figure 1.

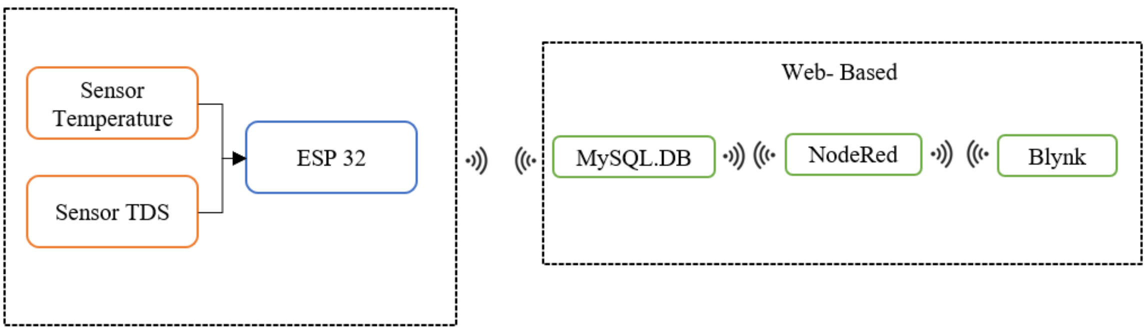

Fig. 1. System Architecture for Water Quality Monitoring Device.

Sensor inputs-temperature and TDS- are collected via devices programmed through the Arduino Uno. The sensors provide temperature data and, from the TDS sensor, additional values such as electrical conductivity, resistivity, and salinity are derived. The ESP32 microcontroller transmits the data to a MySQL database. Node-RED retrieves the data from the database and forwards it to Blynk for visualization. Blynk functions as a data visualization platform, displaying sensor readings on Android-based devices. In addition to Android, sensor data is also visualized on a dedicated HMI device. Figure 2 shows an explanation of the workflow of the water quality monitoring device system based on the following flowchart.

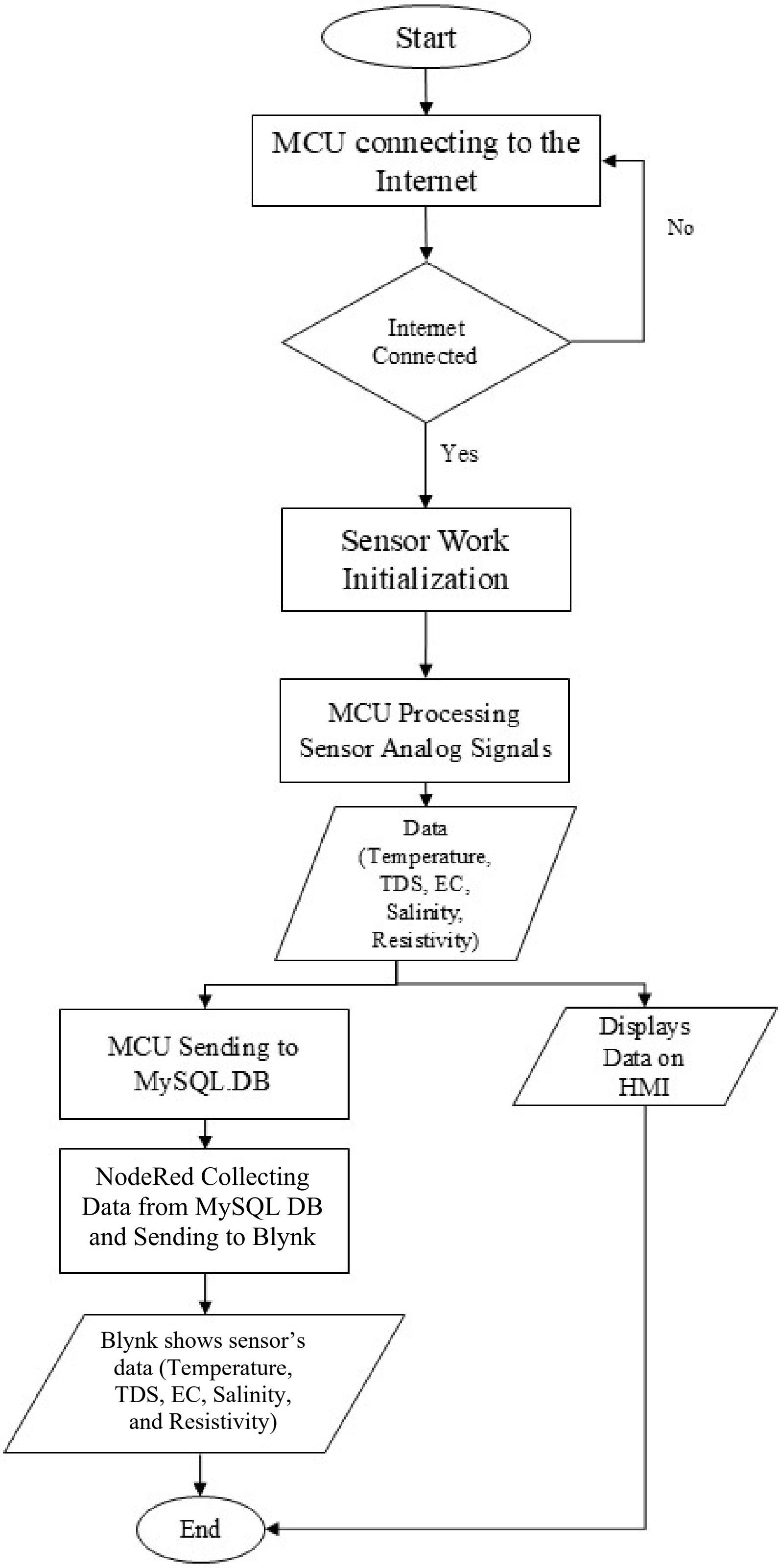

Fig. 2. Flowchart of IoT-based Water Quality Monitoring Device System.

The system operation starts with the Microcontroller Unit (MCU), ESP32, establishing an internet connection. Once connected, the sensors begin collecting analog data, which is then processed by the MCU. This data can be displayed directly on the system device using HMI, or via Android using Blynk. The MCU manages data flow by sending the processed information to a MySQL database. Node-RED retrieves the data and transmits it to Blynk, which serves as the user interface platform. The system provides readings for temperature, TDS, electrical conductivity (EC), salinity, and resistivity based on sensor input.
Subsequently, the water quality monitoring device is tested using various water samples to evaluate its performance. Testing was conducted to evaluate the performance of key components, including the ESP32 microcontroller, DS18B20 temperature sensor, TDS sensor, and the integrated system as a whole. The water samples used consisted of three samples. The following water samples were used in the evaluation:

a) Sample A: Commercial mineral water (Brand A).
b) Sample B: Lake water collected from the campus of Malang State University.

The samples were analyzed using the developed monitoring system and compared with results from the Hanna Instrument HI98194, a standardized measurement device. The data obtained were compared to determine the difference in measurements and to find the relative deviation obtained using the following equation [12]:

$$Relative\ Error\ (\%) = \left|\frac{y-x}{x}\right| \times 100\% \qquad (1)$$

Where y represents the values measured by the system's sensor, and x represents the values obtained from the standard measuring instrument.

Results and Discussion

The system was developed using two sensor probes: a temperature sensor and a TDS sensor. The TDS sensor probe was used to measure several parameters, including TDS, electrical conductivity (EC), resistivity, and salinity. The two probes can be seen in Figure 3. The sensor probes are connected to an ESP32 microcontroller, selected for its built-in Wi-Fi capabilities.

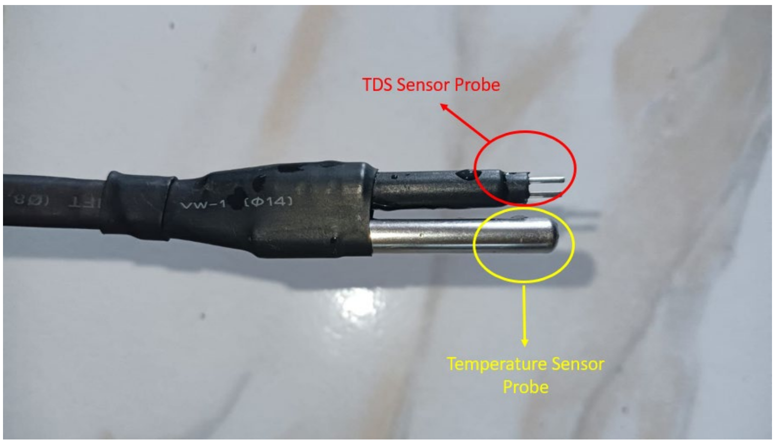

Fig. 3. Sensor probes used on the system.

As illustrated in the flowchart, the sensors read water quality parameters and generate analog signals, which are then processed by the ESP32. The measured water quality data can be displayed directly through the Human Machine Interface (HMI) in the form of a touchscreen display. Integrating HMI into this device enables a more interactive interface, enhanced by touchscreen capabilities, which surpasses the functionality of conventional LCDs [13]. The HMI screen is integrated into the system and housed in an enclosure box, connected to the sensors and the MCU (Microcontroller Unit). Figure 4 displays the interface used to show the measured water quality parameters, namely temperature, TDS, EC, resistivity, and salinity.

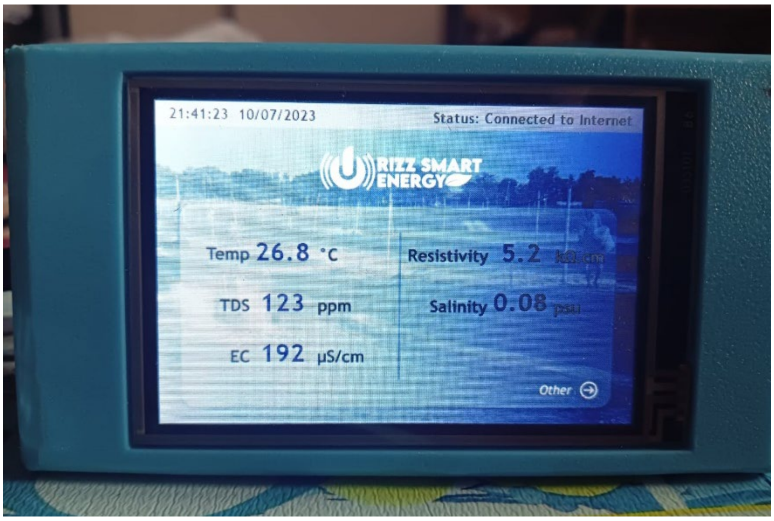

Fig. 4. Interface display on HMI's device.

Blynk is used as the interface to display the water quality measurement results. This software is commonly used in IoT applications and is accessible via Android or web platforms. First, the data processed by the MCU is transmitted to a MySQL database. Next, Node-RED, which functions as a data handler, retrieves the uploaded data from the database and is tasked with sending the data to Blynk. By utilizing Blynk technology, data processing becomes significantly more efficient compared to using a microSD card for data storage, as data can be stored in the cloud and accessed via the internet at anytime, thereby reducing production costs [14]. In Figure 5, the Blynk interface displays the results of water quality parameter measurements accessed via Android.

Fig. 5. Blynk interface on android.

The system was tested by collecting water quality data from two samples and comparing the results using the Hanna Instrument HI98194. Comparisons are made to obtain relative deviations. Where then the relative deviation is known to be the accuracy of the system that has been created. Data were recorded over a 50 second period, with measurements taken every 5 seconds. The comparative results for each water quality parameter are presented in the tables below.

Table 1. Temperature measurement results on the system and HI98194.

Temperature Measurement (°C)							
Sample A				Sample B			
System	HI98194	Difference	Relative Deviation (%)	System	HI98194	Difference	Relative Deviation (%)
27.8	27.83	-0.03	0.11	27.6	27.86	-0.26	0.93
27.8	27.9	-0.1	0.36	27.6	27.92	-0.32	1.15
27.8	27.92	-0.12	0.43	27.7	27.94	-0.24	0.86
27.8	27.92	-0.12	0.43	27.7	27.96	-0.26	0.93
27.8	27.92	-0.12	0.43	27.7	27.94	-0.24	0.86
27.8	27.92	-0.12	0.43	27.7	27.95	-0.25	0.89
27.8	27.91	-0.11	0.39	27.7	27.95	-0.25	0.89
27.8	27.91	-0.11	0.39	27.7	27.96	-0.26	0.93
27.8	27.89	-0.09	0.32	27.7	27.96	-0.26	0.93
27.8	27.88	-0.08	0.29	27.7	27.96	-0.26	0.93

Table 1 shows that temperature measurements recorded by the system were relatively stable, whereas on the HI98194 device, the temperature readings are more varied. These variations may be attributed to the sensitivity and resolution differences between the devices. The highest deviation value in sample A measured by the system was 0.43%, while the lowest was 0.11%. In sample B, the highest deviation is 1.15%, while the lowest deviation is 0.86%. This shows that the performance of the temperature sensor in the system being created is appropriate because it has a relatively small shift. The treatment given to each sample was the same, where the room temperature, sample water's volume, and the measurement time were constant. An observation of note during temperature measurements was that the system produced more consistent readings than the measurements produced by the HI98194, which fluctuated even within a small range. The recorded temperature measurements showed low deviation. However, compared to the device developed by Chuzaini (2022), higher measurement accuracy was achieved due to its ability to detect temperature up to two decimal places, enabling more precise and specific readings [10,15].

Table 2. TDS measurement results on the system and HI98194.

TDS Measurement (ppm)							
Sample A				Sample B			
System	HI98194	Difference	Relative Deviation (%)	System	HI98194	Difference	Relative Deviation (%)
180	185	-5	2.70	315	329	-14	4.26
180	185	-5	2.70	315	328	-13	3.96
179	182	-3	1.65	314	328	-14	4.27
179	181	-2	1.10	313	328	-15	4.57
178	181	-3	1.66	313	329	-16	4.86
177	180	-3	1.67	314	329	-15	4.56
179	180	-1	0.56	315	330	-15	4.55
180	179	1	0.56	316	329	-13	3.95
176	178	-2	1.12	315	330	-15	4.55
176	178	-2	1.12	315	330	-15	4.55

In Table 2, the readings taken by the TDS sensor regarding TDS levels in water have varying values. In sample A, the highest deviation was 2.70% and the lowest deviation was 0.56%. Meanwhile, in sample B, the highest deviation value was higher than sample A, namely 4.86%, and the lowest was 3.95%. The difference in measurements that occur in sample A and sample B is relatively the same. To eliminate errors in differences in measurements made by the system with the HI98194 standard measuring instrument, a recalibration process is required in the programming of the TDS level readings on the system that has been created. Based on the results above, adding a different value can be a solution to adjust the measurements made by the system on HI98194 so that systematic errors can be reduced and measurements obtained that are close to the results of standardized measuring instruments. However, the interesting thing is that the measurements made by the system tend to be more stable in the measured TDS levels compared to the HI98194 which experienced fluctuations, especially in the measurement of sample A.

Table 3. EC measurement results on the system and HI98194.

EC Measurement (μS/cm)							
Sample A				Sample B			
System	HI98194	Difference	Relative Deviation (%)	System	HI98194	Difference	Relative Deviation (%)
360	375	-15	4.00	630	658	-28	4.26
360	370	-10	2.70	630	656	-26	3.96
358	364	-6	1.65	628	656	-28	4.27
358	363	-5	1.38	626	657	-31	4.72
356	361	-5	1.39	626	658	-32	4.86
354	360	-6	1.67	628	657	-29	4.41
358	359	-1	0.28	630	659	-29	4.40
360	358	2	0.56	632	658	-26	3.95
352	357	-5	1.40	630	660	-30	4.55
352	357	-5	1.40	630	660	-30	4.55

Table 4. Resistivity measurement results on the system and HI98194.

Resistivity Measurement (kΩ.cm)							
Sample A				Sample B			
System	HI98194	Difference	Relative Deviation (%)	System	HI98194	Difference	Relative Deviation (%)
0.16	0.18	-0.02	11.11	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67
0.16	0.17	-0.01	5.88	1.4	1.5	-0.1	6.67

Table 5. Salinity measurement results on the system and HI98194.

Salinity Measurement (psu)							
Sample A				Sample B			
System	HI98194	Difference	Relative Deviation (%)	System	HI98194	Difference	Relative Deviation (%)
0.16	0.18	-0.02	11.11	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38
0.16	0.17	-0.01	5.88	0.29	0.32	-0.03	9.38

In Table 3, the EC measurements carried out by the system have quite a large difference. This can be seen in the deviation that occurred in the measurements of sample A and sample B which had the highest deviations of 8.80% and 3.64% respectively. This quite large deviation occurred because the EC level measurement was carried out using the same sensor probe, namely the TDS sensor. The EC value itself is obtained using the relationship equation between TDS and EC. Thus, a lack of appropriate calibration can result in quite large differences between measurements and measurement results with standardized measuring instruments. The stability of the system in EC measurements also looks more stable, especially in measuring sample A against the HI98194 standard measuring instrument. This also occurs in the resistivity and salinity measurements shown in Table 4 and Table 5. The resistivity and salinity values are also taken based on the equation of the relationship between TDS, EC, resistivity and salinity. However, even though there is a large deviation, the difference in measurements made using the system that has been created when compared with standard measuring instruments has a relatively small difference, so it is considered to have met the measurement tolerance. The deviation value of the resistivity itself in sample A and sample B has a maximum value of 11.11% and 6.67% respectively. Meanwhile, for salinity values, the system's highest deviation from the standardized instrument measurement results in sample A was 11.11% and 9.38%.

Based on the results of the measurements that have been carried out, further recalibration is required for TDS, EC, resistivity and salinity measurements in order to obtain more accurate results that are close to the measurement results of standardized measuring instruments. So, later the application of the water quality monitoring system that has been created can be easily used with high measurement validity.

Conclusion

A water quality monitoring system was successfully developed and implemented, integrating sensor data with real time display capabilities. The system displays water quality measurements through both an Android application (using Blynk) and a Human Machine Interface (HMI) device. System testing of the temperature sensor demonstrated reliable and stable measurements, comparable to standard instruments. However, recalibration of the TDS sensor is required to enhance measurement accuracy and consistency to match standardized measuring instruments. Such recalibration would increase the system's potential for practical application in aquaculture environments.

Acknowledgment

The authors would like to especially thank the LPPM (Institute for Research and Community Service) of the State University of Malang which has assisted in providing research funding with contract number 5.4.571/UN32.20.1/LT/2023.

References

[1] Y. Rohmawati and K. Kustomo, “Analisis Kualitas Air pada Reservoir PDAM Kota Semarang Menggunakan Uji Parameter Fisika, Kimia, dan Mikrobiologi, serta Dikombinasikan dengan Analisis Kemometri,” *Walisongo Journal of Chemistry*, vol. 3, no. 2, p. 100, 2020, doi: 10.21580/wjc.v3i2.6603.

[2] Supono, *Manajemen Kualitas Air untuk Budidaya Udang*. 2018.

[3] I. F. Hastari, R. Kurnia, and M. M. Kamal, “Analisis kesesuaian budidaya KJA Ikan Kerapu menggunakan SIG Di Perairan Ringgung Lampung,” *Jurnal Ilmu dan Teknologi Kelautan Tropis*, vol. 9, no. 1, pp. 151–159, 2017.

[4] C. P. Paruntu, “Budidaya Ikan Kerapu (Epinephelus tauvina Forsskal, 1775) dan Ikan Beronang (Siganus canaliculatus Park, 1797) dalam Karamba Jaring Apung dengan Sistim Polikultur,” *e-Journal BUDIDAYA PERAIRAN*, vol. 3, no. 1, pp. 1–10, 2019, doi: 10.35800/bdp.3.1.2015.6924.

[5] M. E. Eshmat and N. Abdul, “Analisis Kondisi Kualitas Air Pada Budidaya Ikan Kerapu Tikus (Cromileptes altivelis) DI SITUBONDO ANALYSIS,” vol. 5, no. 1, pp. 1–4, 2013.

[6] G. Valentino, A. A. Damai, and H. Yulianto, "ANALISIS KESESUAIAN PERAIRAN UNTUK BUDIDAYA IKAN KERAPU MACAN (Epinephelus fuscoguttatu) DI PERAIRAN PULAU TEGAL KECAMATAN TELUK PANDAN KABUPATEN PESAWARAN," *e-Jurnal Rekayasa dan Teknologi Budidaya Perairan*, vol. 6, no. 2, p. 705, 2018, doi: 10.23960/jrtbp.v6i2.p705-712.

[7] T. Abinaya, J. Ishwarya, and M. Maheswari, "A Novel Methodology for Monitoring and Controlling of Water Quality in Aquaculture using Internet of Things (IoT)," *2019 International Conference on Computer Communication and Informatics, ICCCI 2019*, pp. 1–4, 2019, doi: 10.1109/ICCCI.2019.8821988.

[8] J. Y. Lin, H. L. Tsai, and W. H. Lyu, "An integrated wireless multi-sensor system for monitoring the water quality of aquaculture," *Sensors*, vol. 21, no. 24, 2021, doi: 10.3390/s21248179.

[9] S. Sobri, P. Prayitno, B. Basino, and N. Nurhayat, "Automatic Water Quality Monitoring System With Real- Time Data Type Based on Internet of Things (IOT) for Vannamei Shrimp Farming," *Urecol Journal. Part E: Engineering*, vol. 1, no. 2, pp. 52–63, 2021.

[10] F. Chuzaini, D. Wedi, S. Mata, A. Grogolan, D. Ngunut, and S. Tirta, "IoT Monitoring Kualitas Air dengan Menggunakan Sensor Suhu , pH , dan Total Dissolved Solids (TDS)," *Jurnal Inovasi Fisika Indonesia*, vol. 11, no. 3, pp. 46–56, 2022.

[11] Y. Adityas, M. Ahmad, M. Khamim, K. Sofi, and S. R. Riady, "Water Quality Monitoring System with Parameter of pH, Temperature, Turbidity, and Salinity Based on Internet of Things," *JISA(Jurnal Informatika dan Sains)*, vol. 4, no. 2, pp. 138–143, 2021, doi: 10.31326/jisa.v4i2.965.

[12] G. A. Pauzi, M. A. Syafira, A. Surtono, and A. Supriyanto, "Aplikasi IoT Sistem Monitoring Kualitas Air Tambak Udang Menggunakan Aplikasi Blynk Berbasis Arduino Uno," *JURNAL Teori dan Aplikasi Fisika*, vol. 05, no. 02, pp. 1–8, 2017.

[13] Karan R. Chandalwar, Nikhita A. Barde, Shirisha S. Pureddi, Tejasvi Uike, Naveen Yadgiri, and Prof. Mahesh Dumbere, "Water Quality Monitoring System Based on IoT," *International Journal of Advanced Research in Science, Communication and Technology*, pp. 744–751, Nov. 2024, doi: 10.48175/IJARSCT-22300.

[14] R. Arisandi, A. Purno Wahyu W, A. Purno, and W. W. Jumanji -, "DESIGN OF A PROTOTYPE OF WATER QUALITY PHYSICS MEASURING EQUIPMENT BASED ON MICROCONTROLLER."

[15] T. Asyhar and K. Sekarsari, "RANCANG BANGUN MONITORING TOTAL DISSOLVED SOLIDS PADA AIR TANAH BERBASIS IoT," *EPIC Journal of Electrical Power Instrumentation and Control*, vol. 4, no. 2, p. 149, Dec. 2021, doi: 10.32493/epic.v4i2.1491.