



## **IoT- Based Sensor Applications for Water Quality Monitoring in Intensive Aquaculture Systems**

**Faiz Muqorri Kaaffah<sup>1</sup>, Khaerul Manaf<sup>2</sup>, Beki Subaeki<sup>3</sup>**

<sup>1</sup>UIN Siber Syekh Nurjati Cirebon

<sup>2,3</sup>Universitas Sangga Buana Bandung

Email: [faiz@syekh Nurjati.ac.id](mailto:faiz@syekh Nurjati.ac.id), [khaerul.manaf@usbypkp.ac.id](mailto:khaerul.manaf@usbypkp.ac.id) [beki.subaeki@usbypkp.ac.id](mailto:beki.subaeki@usbypkp.ac.id)

### **ABSTRACT**

Intensive aquaculture requires strict water quality monitoring because fluctuations in parameters such as temperature, pH, dissolved oxygen, and ammonia can cause stress and even mass mortality among farmed organisms. Accurate and timely monitoring is a critical operational requirement to ensure the sustainability and profitability of intensive aquaculture operations in meeting global demand for animal protein.

This study aims to design, develop, and test a comprehensive, cost-effective IoT sensor system for real-time water quality monitoring in intensive aquaculture ponds. By integrating multi-parameter sensors into a platform connected to an automated aeration system, the system sends early warnings and action recommendations to farmers via a mobile app in areas with limited connectivity.

The methodology employs a Systematic Literature Review (SLR), a systematic, explicit, and reproducible approach to identify, evaluate, and synthesize relevant empirical evidence from the scientific literature. The SLR produces a comprehensive and objective synthesis of research findings, minimizes bias, and provides an evidence-based foundation for decision-making, following a structured protocol for the critical evaluation of study quality and relevance. The discussion covers four categories: the basic implementation of an IoT system monitoring key parameters provides real-time data and early warnings to boost productivity at low cost—a game-changer that minimizes risks and reliance on manual labor; connectivity innovations using LoRa technology transmit sensor data without adequate WiFi or cellular infrastructure, eliminating adoption barriers for small-to-medium-scale farmers; commodity-specific parameter expansion using TDS and turbidity sensors achieving high accuracy with an error rate <0.5% for sensitive aquaculture such as shrimp farming; system integration and automated response demonstrating the integration of sensors with automatic feed-dispensing actuators to create a responsive and autonomous closed-loop system.

This study concludes that IoT systems monitoring fundamental parameters such as temperature, pH, and DO are viable and provide significant benefits in the form of increased productivity through proactive management. LoRa technology successfully overcomes connectivity challenges in remote areas, expanding the scope of IoT applications. Monitoring specific parameters with high accuracy is key to cultivating sensitive commodities. The future of precision aquaculture lies in the integration of IoT monitoring with automated control to create a responsive and autonomous cultivation environment.

**Keywords:** IoT, water quality, intensive ponds, real-time monitoring, aquaculture automation

### **INTRODUCTION**

Intensive aquaculture is a vital pillar in meeting the ever-increasing global demand for animal protein. In this system, water quality is an absolute determining factor that influences the health, growth, and survival of farmed organisms. Parameters such as temperature, pH, dissolved oxygen (DO), ammonia, and turbidity must be closely monitored because even minor fluctuations can trigger stress, disease

outbreaks, and mass mortality, resulting in significant economic losses. Therefore, accurate and timely water quality monitoring is not merely a best practice but a critical operational necessity to ensure the sustainability and profitability of intensive aquaculture operations.

Recent developments in aquaculture are marked by a transition toward the Industry 4.0 era, where digital technologies such as the Internet of Things (IoT) are being adopted. A key challenge is the reliance on sporadic manual monitoring methods, which are prone to human error and unable to provide early warnings for rapidly changing critical conditions. Other challenges include the high cost of commercial monitoring systems and internet connectivity issues at pond sites, which are often remote. Current research and implementation efforts focus on developing cost-effective, real-time, reliable IoT sensor systems integrated with automated control systems to create “smart ponds” that can be efficiently managed remotely.

Ideal conditions for intensive pond management require continuous (24/7) monitoring of water quality parameters with high accuracy, enabling swift and precise corrective actions before conditions deteriorate and threaten the aquaculture stock. Based on the principles of precision aquaculture, data must be accessible in real-time to support optimal decision-making aimed at maximizing the growth and health of aquatic organisms.

However, real-world conditions in the field show that most farmers still rely on conventional methods, namely manual measurements using portable kits conducted once or twice a day. Data from the Ministry of Marine Affairs and Fisheries and various field studies reveal that the gap between the ideal frequency and scope of data and what is actually measured often results in delayed detection of declining water quality, such as a drop in oxygen levels in the early morning, which leads to the death of fish or shrimp.

This gap arises due to several contributing factors. The primary cause is the financial constraint in purchasing commercial automated monitoring systems, which are often expensive. Additionally, low digital literacy among aquaculture farmers and the lack of supporting infrastructure, such as stable internet connectivity in coastal areas, also pose significant barriers to the adoption of more advanced technologies.

Based on an analysis of these articles, a major research gap has been identified regarding the application of IoT sensors in intensive aquaculture ponds. Although various studies have successfully demonstrated IoT system prototypes for monitoring basic parameters such as temperature, pH, and DO, there remains a gap in the development and testing of fully integrated systems that combine multi-parameter monitoring (including ammonia and turbidity) with automatic control mechanisms (such as aeration or feeding) at a real-world operational scale. Furthermore, research that thoroughly examines sustainability aspects, sensor durability in corrosive pond environments, and business models that make this IoT solution affordable and easily adoptable by small- and medium-scale farmers remains relatively limited.

This study aims to design, develop, and test a comprehensive and cost-effective IoT sensor system for real-time water quality monitoring in intensive shrimp/fish ponds. The specific objective is to integrate multi-parameter sensors (temperature, pH, DO, TDS, turbidity, and ammonia) into a single platform that not only monitors but also connects to an automated aeration system, and is capable of sending early warnings and action recommendations to farmers via a mobile app, even in areas with limited connectivity.

This research is highly urgent given the high rate of harvest failure in intensive pond aquaculture, which is often triggered by poor water quality. The resulting economic losses amount to billions of rupiah annually. Therefore, the development of a reliable, real-time, and affordable monitoring system is a critical solution to minimize risks, increase national productivity, and support food security, while simultaneously driving digital transformation in Indonesia's sustainable aquaculture sector..

## METHOD

The methodology used in this study is a Systematic Literature Review (SLR), which is a systematic, explicit, and reproducible research approach designed to identify, evaluate, and synthesize all relevant empirical evidence from the scientific literature pertaining to a specific research question. The primary objective of an SLR is to produce a comprehensive and objective synthesis of available research findings, thereby minimizing bias and providing an evidence-based foundation for decision-making in both academic and practical contexts. Unlike traditional literature reviews, an SLR follows a structured protocol that enables researchers to conduct a critical evaluation of the quality and relevance of the studies examined.

The implementation of the SLR in this study followed several systematic steps, beginning with the formulation of a clear and specific research question to guide the entire literature search and analysis process. The next stage involved developing a comprehensive literature search strategy, including the identification of academic databases to be used, the selection of appropriate keywords, and the establishment of Boolean operators to maximize the relevance of search results. Once the search strategy was established, the researchers then set strict inclusion and exclusion criteria to ensure that only relevant, high-quality literature would be analyzed further.

The literature selection process is conducted in stages using the PRISMA Flow Diagram, which serves as a visual tool to document the number of articles at each screening stage, from initial identification, screening based on titles and abstracts, eligibility assessment through full-text reading, to the final inclusion of articles meeting all criteria. The next stage is data extraction from the selected articles, where relevant information such as research objectives, methodology, key findings, and conclusions is systematically collected using a pre-designed data extraction form. The final step is the analysis and synthesis of findings from the reviewed literature, where patterns, key themes, and research gaps are identified to produce comprehensive, evidence-based conclusions.

Based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram, the article selection process in this study was conducted through four main systematic and structured stages to ensure that only the most relevant and high-quality literature was analyzed. This process began with the initial identification stage and concluded with the final inclusion, resulting in ten articles as the main corpus of the systematic review.

During the identification stage, a comprehensive literature search was conducted across four major academic databases—Scopus, Web of Science, IEEE Xplore, and ScienceDirect—using a combination of predefined keywords aligned with the research questions. The initial search yielded a total of 687 articles indexed in various reputable scientific journals. These articles covered publications from the past five years to ensure the relevance and recency of the information reviewed. All identified articles were then collected and managed using reference management software to facilitate the subsequent selection process.

Entering the screening phase, the first step was to remove duplicate articles appearing in more than one database. The deduplication process resulted in a reduction of 143 articles, leaving 544 unique articles that were then further screened. Screening was conducted by reviewing titles and abstracts to assess initial relevance to the research topic. At this stage, 398 articles were excluded for various reasons, including topic mismatch with the research focus, irrelevant context, as well as articles that were too general or lacked sufficient analytical depth. Additionally, articles that were editorials, opinion pieces, or had not undergone peer review were also excluded at this stage. Consequently, 146 articles advanced to the next stage for a more in-depth eligibility assessment.

During the eligibility stage, all 146 remaining articles were downloaded in full-text format and read thoroughly to evaluate their compliance with the established inclusion criteria. This eligibility assessment was conducted independently by two researchers to minimize subjective bias, and any discrepancies were resolved through consensus discussions. The criteria used included the methodological quality of the research, clarity of data presentation, relevance to the research context, and significant contribution to the research questions posed. A total of 136 articles were excluded at this stage for various reasons. The main reasons for exclusion included insufficiently rigorous or inadequately described methodology, research results that were not substantial or not supported by strong empirical data, inconsistency with the criteria for the population or intervention under study, and articles that presented only descriptive literature reviews without critical analysis. Several articles were also excluded due to limited access to complete data or non-transparent methodological information.

After undergoing a rigorous evaluation during the eligibility phase, ten articles remained that met all the established inclusion and exclusion criteria. These ten articles were then included in the inclusion phase as the final corpus for in-depth analysis and synthesis of findings. The selected articles represent studies with high methodological quality, strong thematic relevance, and significant contributions to the advancement of knowledge in the field under study, thereby comprehensively addressing the research questions based on valid scientific evidence.

## RESULTS AND DISCUSSION

No	ARTICLE TITTLE	MAIN FINDINGS
1	Application of Internet of Things Technology in Monitoring Water Quality in Fishponds (Putra et al., 2024)	IoT technology enables real-time monitoring of water quality parameters in intensive fish ponds—such as temperature, dissolved oxygen, pH, ammonia levels, and turbidity—thereby improving fish productivity and welfare while allowing for proactive management of water conditions to prevent environmental damage.
2	The monitoring system for water quality is based on the internet of things (iot) and uses a tds sensor (Zafi et al., 2024)	An IoT-based water quality monitoring system for aquaculture ponds using TDS sensors and an ESP32 microcontroller, enabling real-time monitoring and categorization of water quality into safe, caution, and poor status based on TDS thresholds.

No	ARTICLE TITTLE	MAIN FINDINGS
3	A Low-Cost IoT-Based Solution for Water Quality Monitoring in Aquaculture 4.0 (De Freitas et al., 2024)	proposes a low-cost IoT-based solution for water quality monitoring in aquaculture, enabling automatic data collection and real-time alerts. This system improves decision-making in intensive pond environments, boosting productivity and reducing risks associated with manual measurements.
4	Application of the Internet of Things technology (IoT) in Designing an Automatic Water Quality Monitoring System for Aquaculture Ponds (Huy et al., 2020)	An IoT-based automated water quality monitoring system for aquaculture ponds, continuously measuring temperature, pH, and dissolved oxygen (DO), with data transmitted to smart devices and alerts sent to farmers when DO levels drop below the threshold.
5	IoT Enabled Advancement Water Quality Monitoring System for Pond Management & Environment Conservation (Without WIFI) (“IoT Enabled Advancement Water Quality Monitoring System for Pond Management & Environment Conservation (Without WIFI),” 2025)	An IoT-enabled water quality monitoring system utilizing sensors for turbidity, TDS, and pH. It uses LoRa technology for data transmission, facilitating real-time monitoring and water quality management in intensive pond environments.
6	IoT-Based Real-Time Water Quality Monitoring in Aquaculture Systems Enhancing Aquatic Species Health (Kasu et al., 2023)	An IoT-based system utilizing various sensors, including turbidity and gas sensors, for real-time water quality monitoring in aquaculture systems, improving the health of aquatic species and enhancing the efficiency and sustainability of intensive pond operations.
7	Pengembangan Sistem Monitoring Kualitas Air dan Kendali Pakan Otomatis untuk Budidaya Ikan Berbasis Internet of Things (Putri & Arinal, 2025)	An IoT-based water quality monitoring system using sensors such as the DS18B20, TDS, and turbidity sensors enables real-time data monitoring and automated feeding, improving efficiency in aquaculture management for intensive pond systems.
8	Sistem Monitoring Informasi Kualitas dan Kekeruhan Air Tambak Berbasis Internet of Things (Melangi et al., 2022)	An IoT-based monitoring system uses TDS and SEN0189 sensors to assess water quality and turbidity in intensive ponds, providing real-time data to smartphones, thereby enhancing farmers’ ability to manage aquaculture effectively.
9	A Proposed Model of Fishpond Water Quality Measurement and Monitoring System based on Internet of Things (IoT)	IoT technology automates real-time measurement and monitoring of water quality parameters in fish ponds, ensuring optimal conditions for fish growth and survival, while

No	ARTICLE TITTLE	MAIN FINDINGS
	(Ismail et al., 2020)	enabling timely preventive actions to minimize losses and boost productivity.
10	Pengembangan sistem terintegrasi berbasis iot (internet of things) untuk monitoring dan kontrol kualitas air pada budidaya tambak udang daratan (Sari et al., 2024)	An IoT-based system for monitoring water quality in shrimp ponds, utilizing sensors for turbidity, TDS, pH, and ammonia. It achieves high accuracy, with an error rate ranging from 0.01% to 0.12%, ensuring effective water quality management.

## Discussion

A study conducted by Putra et al. (2024) examined the application of IoT technology to monitor critical water quality parameters—such as temperature, dissolved oxygen, pH, ammonia, and turbidity—in intensive fish ponds in real time. The main findings of this study indicate that this continuous monitoring capability enables proactive water management, allowing changes in conditions to be anticipated before they harm the fish. The key conclusion is that this system not only enhances fish productivity and welfare by maintaining an optimal environment but also significantly contributes to preventing environmental damage that can result from intensive aquaculture.

Research conducted by Zafi et al. (2024) developed an IoT-based water quality monitoring system focused on the use of TDS (Total Dissolved Solids) sensors integrated with an ESP32 microcontroller. The findings of this study indicate that the system successfully monitors and categorizes water quality into safe, caution, and poor statuses in real-time based on predefined TDS thresholds. The main conclusion of this study is that this TDS-based approach provides an effective and direct method for farmers to assess the overall condition of pond water, enabling a rapid response to potential quality deterioration.

Research conducted by De Freitas et al. (2024) designed a low-cost IoT-based solution aimed at monitoring water quality within the Aquaculture 4.0 framework. Their findings indicate that this system is capable of automatically collecting data and providing real-time alerts, thereby addressing the limitations of slow and error-prone manual measurements. The main conclusion of this study confirms that the adoption of such solutions significantly improves decision-making quality in intensive ponds, ultimately leading to increased productivity and reduced risk of economic losses.

Research conducted by Huy et al. (2020) designed an IoT-based automated monitoring system that continuously measures key parameters such as temperature, pH, and dissolved oxygen (DO) in aquaculture ponds. A key finding of this study is the system’s ability to transmit data directly to farmers’ smart devices and automatically send alerts when DO levels drop below a critical threshold. The main conclusion is that this early warning feature is crucial for preventing mass fish mortality due to oxygen deficiency, thereby enabling timely intervention and minimizing losses.

Research conducted by “IoT Enabled Advancement...” (2025) proposes a water quality monitoring system utilizing sensors for turbidity, TDS, and pH, with a primary advantage in LoRa communication technology. The study’s findings highlight that LoRa enables long-range data transmission without reliance on WiFi networks, making it highly suitable for pond locations that are often remote. The main conclusion is that this system facilitates real-time monitoring and reliable water quality

management in intensive aquaculture environments, addressing connectivity challenges that have long been a constraint.

Research conducted by Kasu et al. (2023) developed an IoT-based system utilizing sensor arrays, including turbidity and gas sensors, to monitor water quality in real-time within aquaculture systems. The findings of this study indicate that comprehensive monitoring of these various parameters has a direct impact on improving the health of aquatic species. The main conclusion is that the implementation of such a system not only improves operational efficiency but also promotes the long-term sustainability of intensive pond operations by creating a more stable and controlled environment.

Research conducted by Putri & Arinal (2025) developed an integrated system that combines IoT-based water quality monitoring (using DS18B20, TDS, and turbidity sensors) with automated feed control. The findings of this study indicate that this integration results in significant efficiency gains in the management of intensive fish farming. The main conclusion is that this system not only monitors environmental conditions but also actively responds through precise feeding, thereby optimizing growth and reducing feed wastage.

Research conducted by Melangi et al. (2022) designed an IoT-based monitoring system using TDS and SEN0189 sensors to specifically assess water quality and turbidity levels in ponds. The main finding of this study is that the system successfully provided real-time data that farmers could access directly via their smartphones. The conclusion of this study confirms that this easy accessibility to data directly enhances farmers' capacity and ability to manage their aquaculture operations more effectively and informatively.

Research conducted by Ismail et al. (2020) proposed a model for an IoT-based fish pond water quality measurement and monitoring system. The findings of this study emphasize the aspect of real-time automation of water quality parameter measurements. The main conclusion is that this system ensures optimal water conditions for fish growth and survival, while also enabling timely preventive actions. This ultimately has the potential to minimize losses and boost overall aquaculture productivity.

Research conducted by Sari et al. (2024) developed an IoT-based system specifically designed to monitor water quality in inland shrimp farming ponds using parameters such as turbidity, TDS, pH, and ammonia. A key finding of this study is the system's high level of accuracy, evidenced by an extremely low error rate ranging from 0.01% to 0.12%. The main conclusion is that this high level of accuracy is crucial for ensuring effective and reliable water quality management, which is a key determinant of success in the sensitive field of shrimp farming.

Based on an in-depth analysis of the main focus and contributions of the ten articles, these studies can be grouped into four categories representing the evolution and specific applications of IoT in aquaculture. The first category is Basic Implementation and Feasibility of IoT Systems, which includes research by Huy et al. (2020), Ismail et al. (2020), and De Freitas et al. (2024). This group demonstrates the foundational elements of IoT monitoring systems, proving the concept that real-time and automated monitoring of basic parameters (temperature, pH, DO) is feasible, cost-effective, and provides tangible benefits in the form of increased productivity and loss prevention. The second category is Innovations in Connectivity and Data Communication, represented by the research "IoT Enabled Advancement..." (2025) and Melangi et al. (2022). This category addresses a major practical challenge in the field—internet connectivity—by proposing and testing alternative solutions such as

LoRa technology, which does not rely on Wi-Fi, thereby expanding the scope of IoT implementation to remote areas. The third category is Expansion of Parameters and Commodity-Specific Monitoring, comprising the studies by Zafi et al. (2024), Sari et al. (2024), and Kasu et al. (2023). This group focuses on expanding the scope of monitoring beyond basic parameters, investigating more specific parameters such as TDS, turbidity, and ammonia, and emphasizing the high accuracy required for sensitive commodities like shrimp. The fourth category is System Integration and Responsive Automation, which represents the pinnacle of IoT system evolution, driven by the research of Putra et al. (2024), Putri & Arinal (2025), and Kasu et al. (2023). This category not only monitors but also integrates monitoring data with other control systems (such as automatic feeders) to create a fully responsive and proactive aquaculture system.

Research in the Basic Implementation and Feasibility of IoT Systems category, conducted by Huy et al., Ismail et al., and De Freitas et al., aims to demonstrate the fundamental value and technical and economic feasibility of applying IoT technology in the context of intensive aquaculture. The primary objective of this category is to transition aquaculture practices from traditional and reactive methods toward data-driven and proactive approaches. Key findings from these studies consistently show that basic IoT systems—which monitor key parameters such as temperature, pH, and dissolved oxygen—successfully provide real-time data that was previously unavailable, enable early warnings for critical conditions (such as DO depletion), and ultimately improve productivity. The collective conclusion of this category is that even with relatively simple and low-cost implementations, IoT technology has proven to be a game-changer capable of minimizing risks, reducing reliance on manual labor, and paving the way for more efficient aquaculture.

Research in the category of Innovations in Data Connectivity and Communication, conducted by “IoT Enabled Advancement...” and Melangi et al., focuses on addressing one of the greatest challenges in IoT implementation in the field: limited internet connectivity in rural and coastal areas, which are often the locations of fish farms. The objective of the research in this category is to design and test reliable, low-power, and long-range alternative communication protocols. Their key findings confirm that technologies such as LoRa (Long Range) are capable of transmitting sensor data from fish farms to gateways or farmers’ smartphones without relying on adequate WiFi or cellular infrastructure. The conclusion of this category is that innovations in this area of connectivity are a critical prerequisite for the democratization and widespread adoption of IoT technology among small- and medium-scale farmers, as they eliminate infrastructure barriers that have long been the primary obstacle.

Research in the Parameter Expansion and Commodity-Specific Monitoring category, conducted by Zafi et al., Sari et al., and Kasu et al., aims to enhance the sophistication and specificity of IoT monitoring systems by expanding the range of monitored parameters and emphasizing high accuracy criteria. The strategic objective of this category is to provide monitoring tools that are not only general-purpose but also highly relevant to the specific needs of certain commodities, such as shrimp, which are highly sensitive to fluctuations in ammonia and turbidity. Key findings from these studies include the validation of TDS and turbidity sensor performance, as well as the achievement of very high accuracy levels (with errors below 0.5%), which is crucial for making informed decisions. In conclusion, advancements in this category are essential for adapting generic IoT solutions into precise and reliable management tools for the intensive cultivation of high-value commodities.

Research in the System Integration and Responsive Automation category, conducted by Putra et al., Putri & Arinal, and Kasu et al., represents the cutting edge of IoT research for aquaculture, with the goal of creating fully integrated and autonomous farming systems. The objective of this category is to move beyond passive monitoring functions toward systems capable of performing corrective actions or optimizations automatically based on received data. Their key findings demonstrate the successful integration of IoT sensor modules with actuators, such as automatic feeding systems, enabling immediate and precise responses to changing water conditions. The conclusion of this category is that the future of intensive aquaculture lies in such closed-loop systems, where real-time monitoring is directly translated into proactive management actions, thereby maximizing overall efficiency, growth, and sustainability.

### CONCLUSION

1. IoT systems that monitor fundamental parameters such as temperature, pH, and dissolved oxygen (DO) are already viable and provide significant benefits in the form of increased productivity through proactive management.
2. Technologies such as LoRa have successfully addressed connectivity challenges in remote areas, thereby expanding the scope of IoT applications.
3. Monitoring specific parameters such as TDS and turbidity with high accuracy is key to cultivating sensitive commodities like shrimp.
4. The future of precision aquaculture lies in integrating IoT monitoring with automated control systems to create responsive and autonomous cultivation environments.

### REFERENCES

- Darshana Dandina, & Dr. Shivprasad K M. (2025). Ai-Powered Emergency Alert System for Elderly People Using Health Vitals. *International Research Journal on Advanced Engineering Hub (IRJAEH)*, 3(09), 3612–3618. <https://doi.org/10.47392/IRJAEH.2025.0527>
- De Freitas, F. A., Nobrega, O. de O., Lins, F. A. A., Santos, J. F. Dos, Galvez, A. O., & Santos, E. P. Dos. (2024). A Low-Cost IoT-Based Solution for Water Quality Monitoring in Aquaculture 4.0. *2024 IEEE 10th World Forum on Internet of Things, WF-IoT 2024*, 517–522. <https://doi.org/10.1109/WF-IOT62078.2024.10811429>
- Eka Kusuma Pratama. (2025). Integration of IoT Sensors in Early Warning Systems for Mass Fish Deaths in Fish Farms. *Journal of Artificial Intelligence and Engineering Applications (JAIEA)*, 4(3), 1915–1919. <https://doi.org/10.59934/JAIEA.V4I3.1046>
- Huy, N. Q., Giang, V. T. T., Quan, L. V., & Cuong, H. V. T. (2020). Application of the Internet of Things technology (IoT) in Designing an Automatic Water Quality Monitoring System for Aquaculture Ponds. *Vietnam Journal of Agricultural Sciences*, 3(2), 624–635. <https://doi.org/10.31817/10.31817/VJAS.2020.3.2.06>
- IoT Enabled Advancement Water Quality Monitoring System for Pond Management & Environment Conservation (Without WIFI). (2025). *Journal on Electronic and Automation Engineering*, 4(2 June 2025), 129–133. <https://doi.org/10.46632/JEAE/4/2/19>
- Ismail, R., Shafinah, K., & Latif, K. (2020). A Proposed Model of Fishpond Water Quality Measurement and Monitoring System based on Internet of Things (IoT). *IOP Conference Series: Earth and Environmental Science*, 494(1). <https://doi.org/10.1088/1755-1315/494/1/012016>

- Kasu, S. A., Mathukumalli, S., Done, H., Yalavarthy, G., & Veeramalla, S. K. (2023). lot-based real-time water quality monitoring in aquaculture systems enhancing aquatic species health. *Intelligent Engineering Applications and Applied Sciences for Sustainability*, 406–424. <https://doi.org/10.4018/979-8-3693-0044-2.CH021>
- Melangi, S., Asri, M., & Hulukati, S. A. (2022). Sistem Monitoring Informasi Kualitas dan Kekekruhan Air Tambak Berbasis Internet of Things. *Jambura Journal of Electrical and Electronics Engineering*, 4(1), 77–82. <https://doi.org/10.37905/JJEEE.V4I1.12061>
- NGUYEN, D. T., LUONG, T. L., NGUYEN, N. M., NGUYEN, T. Q., LE, N. T. N., TRUONG, C. D., Nguyen Thi Lieu, Ho Van Lam, DINH, Q. K., HUYNH, D. C., VO, V., & NGUYEN, T. V. H. (2024). Monitoring Water Quality Parameters in Aquaculture Using Edge Computing. *Vietnam Journal of Catalysis and Adsorption*, 12(2), 135–140. <https://doi.org/10.62239/JCA.2024.047>
- Putra, F. P. E., Ubaidi, U., Saputra, R. N., Haris, F. M., & Barokah, S. N. R. (2024). Application of Internet of Things Technology in Monitoring Water Quality in Fishponds. *Brilliance: Research of Artificial Intelligence*, 4(1), 356–361. <https://doi.org/10.47709/BRILLIANCE.V4I1.4231>
- Putri, S. E., & Arinal, V. (2025). Pengembangan Sistem Monitoring Kualitas Air dan Kendali Pakan Otomatis untuk Budidaya Ikan Berbasis Internet of Things. *Jurnal Indonesia: Manajemen Informatika Dan Komunikasi*, 6(3), 1884–1892. <https://doi.org/10.63447/JIMIK.V6I3.1605>
- Sari, T. E., Satria, E., & Rajak, A. (2024). PENGEMBANGAN SISTEM TERINTEGRASI BERBASIS IOT (INTERNET OF THINGS) UNTUK MONITORING DAN KONTROL KUALITAS AIR PADA BUDIDAYA TAMBAK UDANG DARATAN. *Journal of Science and Applicative Technology*, 8(1), 73. <https://doi.org/10.35472/JSAT.V8I1.1698>
- Wu, G. (2022). Nutrition and Metabolism: Foundations for Animal Growth, Development, Reproduction, and Health. *Advances in Experimental Medicine and Biology*, 1354, 1–24. [https://doi.org/10.1007/978-3-030-85686-1\\_1](https://doi.org/10.1007/978-3-030-85686-1_1)
- Yadav, A., Noori, M. T., Biswas, A., & Min, B. (2023). A Concise Review on the Recent Developments in the Internet of Things (IoT)-Based Smart Aquaculture Practices. *Reviews in Fisheries Science and Aquaculture*, 31(1), 103–118. <https://doi.org/10.1080/23308249.2022.2090228>
- Zafi, A., Saputra, B. D., & Bianto, M. A. (2024). THE MONITORING SYSTEM FOR WATER QUALITY IS BASED ON THE INTERNET OF THINGS (IOT) AND USES A TDS SENSOR. *Indonesian Journal of Engineering, Science and Technology*, 1(2), 49–58. <https://doi.org/10.38040/IJENSET.V1I2.1015>