Solar-based aerator with water quality monitoring in vannamei shrimp pond

I Putu Eka Widya Pratama[1], Friska Aprilia Kusuma[1], Safira Firdaus Mujiyanti[1], Romana Schirhagl[2], Tepy Lindia Nanta[1]
[1]Department of Instrumentation Engineering, Faculty of Vocation, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
[2]Department of Biomedical Engineering, Faculty of Medical Sciences, University of Groningen, Groningen, Netherlands

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ABSTRACT

The water quality is vital for the vannamei shrimp pond's productivity. Manual monitoring at Gunung Anyar's vannamei shrimp pond is time-consuming, ineffective, and potentially harmful. In this research, we developed a real-time monitoring system for the water quality of the vannamei shrimp pond. This monitoring system is integrated with a solar-based aerator. To address this, water quality monitoring in a solar-based aerator system tracks the degree of acidity (pH), temperature, and total dissolved solids (TDS) remotely using a website and real-time mobile phone Android application with 98.57% accuracy and 1.43% error. Seven days of data revealed the degree of acidity between 6.92 and 7.34 is indicated poor conditions of the pond While the temperatures from 23.59 °C to 38.32 °C, and TDS from 628.65 to 652.34 ppm indicate the good condition of the shrimp pond. This real-time monitoring system can help vannamei shrimp farmers monitor the actual conditions of their ponds.

Corresponding Author:

I Putu Eka Widya Pratama
Department of Instrumentation Engineering, Faculty of Vocation, Institut Teknologi Sepuluh Nopember
ITS Sukolilo Campus, Surabaya 60111, Indonesia
Email: eka.widya@its.ac.id

1. INTRODUCTION

Shrimp farming can achieve high production yields by monitoring pond water quality regularly [1] Water quality plays an important role in increasing productivity value because it shows the balance of nutrients and environmental health of ponds, as well as suitability with commodity needs [2]–[5]. Ideal conditions in shrimp pond water that show the balance of oxygen and carbon dioxide can be said to be of good quality when it is in the temperature range of 25-38 °C, and acidity levels of 7.5-8.5. While the range of total dissolved solid (TDS) is ideal <1,000 ppm [6]–[12].

Shrimp pond water quality monitoring based on temperature and TDS needs to be done every day, while the acidity level is enough once a week so that the growth and survival rate of shrimp is high [13]. Monitoring of these parameters needs to be done because the quality of pond water is proportional to the amount of production [14]–[19]. Improving pond water quality can be done by using paddle wheel aerators, especially solar-powered aerators, because there is potential for sunlight irradiation in Surabaya, which has an average of more than 75% during 2019 according to the Surabaya Communication and Information Agency in 2020 [20]–[22]. Currently, farmers of the vannamei shrimp in Gunung Anyar, Surabaya, are still measuring water quality in the form of acidity, temperature, and TDS manually in the pond. This is ineffective and takes a long time until farmers know the quality of water, so it can harm pond ecology.

This research presents a water quality monitoring system designed to facilitate remote real-time monitoring of acidity, temperature, and TDS. Implemented in solar-based aerators, this system can be accessed via a human machine interface (HMI) on a local plant GUI or an Android application. The system aims to provide faster water quality information, enabling farmers to take immediate actions to maintain and optimize water conditions, preventing ecological damage that could harm shrimp health and production value. Therefore, this research is expected to help farmers find faster water quality information so that farmers can immediately take action to maintain and optimize water quality before the occurrence of pond ecological damage that has an impact on decreasing the health and production value of vannamei shrimp.

The following sections of the paper include the methodology, focusing on water quality parameters and the design of the monitoring system. Results and discussion, detailing the performance tests of the sensors and the HMI; and the conclusion, summarizing the effectiveness of the integrated monitoring system. Acknowledgments and references are also included to credit the contributions and sources used in this research.

2. METHOD

2.1. Water quality parameters of vannamei shrimp pond

Water quality is one of the important factors that affect shrimp growth in addition to nutrition, stocking density, sex, genetic variation, and age [23]–[25]. Lack of monitoring and regulation of physicochemical parameters of water quality such as acidity and temperature can lead to production failure by 20%-60%. The acidity of vannamei shrimp pond water during the day is influenced by CO_2 concentration due to the photosynthesis process that occurs in plants around the pond which causes CO_2 concentration to decrease, and acidity levels to increase [26]. At night, vannamei shrimp release CO_2 from respiration so that acidity levels decrease [27]. This has happened to the marine aquaculture facility (FURG-EMA), which if farmers know and handle it too late (more than 30 minutes) can cause failure in almost the entire shrimp production process that is currently underway [28]. In addition, TDS levels influenced by rock weathering and soil runoff from ponds affect plankton growth as natural food for vannamei shrimp [29]–[32].

2.2. Design of water quality monitoring system

The water quality monitoring system design is shown in Figure 1. In which every parameter is measured with PH-4502C sensors, K-type thermocouple sensors, and TDS sensors, which get power from solar panels installed in the aerator. The signal that has been obtained by the three sensors is then processed using ADS1115 and the Max6675 module is then forwarded to ESP32 as a microcontroller.

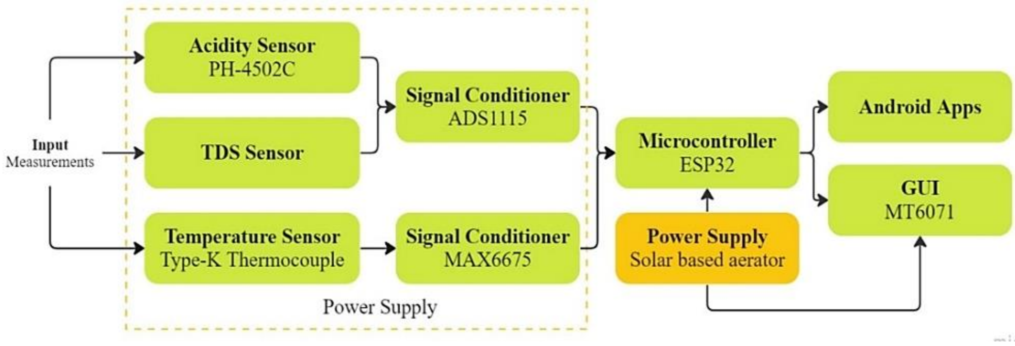
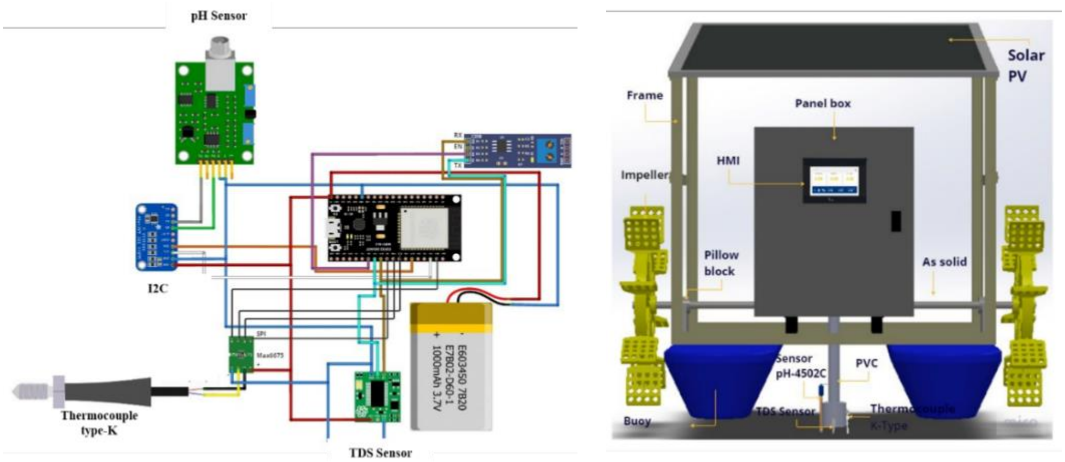


Figure 1. Block diagram of water quality monitoring system

Figure 2(a) shows the electrical wiring diagram of the sensor. In the wiring diagram, the voltage enters through the power terminal from the aerator’s batteries and then flows to the 3 and 5 V lines to provide power supply for all components. The voltage then goes into the module of each sensor to perform readings and the Modbus header with TTL to RS485 as serial communication [33]. All of the sensor readings are displayed in the mobile phone Android application so that the farmers can monitor them in real-time.

The ADS1115 functions as an extender of TDS sensor readings and acidity levels to the microcontroller using I2C. Meanwhile, MAX6675 functions as a signal conditioner from a K-type thermocouple [34], [35]. The data readings that have been processed into digital signals are then displayed by human machine interface (HMI) on the aerator and Android application. Figure 2(b) shows the 3D design of solar-based aerator design equipped with a water quality monitoring sensor for Gunung Anyar vannamei shrimp farm Surabaya located at the bottom of the panel box. The power of the program and hardware are supplied by solar panel energy. The data will be compared by readings from validators with HMI and Android applications, this aims to find out the suitability of the readings between the two. Sampling is carried out directly from the water of Gunung Anyar vannamei shrimp pond, while data collection is carried out simultaneously within a span of one minute.



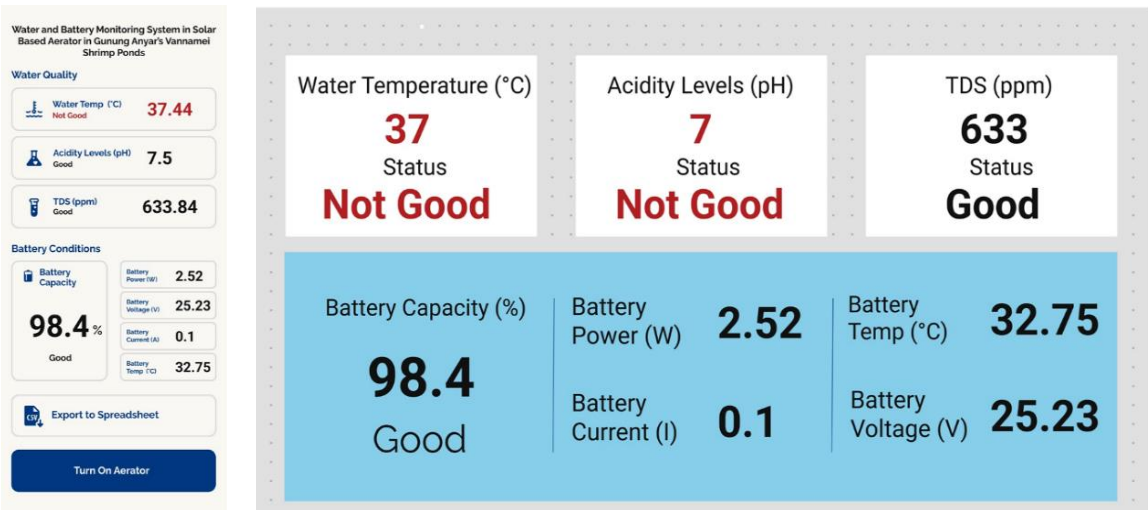
(a) (b)

Figure 2. Design of solar-based water quality monitoring system (a) Electrical wiring diagram and (b) 3D design

3. RESULTS AND DISCUSSION

3.1. Human-machine interface of water quality monitoring system in vannamei shrimp pond

HMI in the form of an Android application on mobile phones and the website will be displayed as shown in Figure 3(a) and 3(b). The readings of each water quality parameter in this study, namely acidity level, temperature, and salinity, will be highlighted in red and indicate a “Poor” status if they fall outside the predetermined range for each parameter. Conversely, if the parameter values remain within the range, they will be highlighted in green and display a “Good” status, indicating that the water quality of the vannamei shrimp pond is still considered ideal and optimal.



(a) (b)

Figure 1. Human machine interface in (a) mobile phone android and (b) website

3.2. Performance test

The equipment testing took place over a week, spanning 24 hours a day at the Gunung Anyar Surabaya vannamei shrimp pond, commencing from Monday, July 17, 2023, at 06:00, until Monday, July 24, 2023. This period was chosen to analyze the water quality in the pond under the condition of the aerator operating every two minutes, with a fifteen-minute interval, for 21 hours, from 15:00 to 11:00 the following day. Between 11:00 and 15:00, the aerator was inactive due to charging, but the water quality monitoring system continued running for 24 hours using voltage and current from the valve regulated lead–acid (VRLA) battery.

3.2.1. Performance test of pH sensor

The measured acidity levels from the 24-hour equipment testing over a week exhibited a data range of 6.74 to 7.34. These fluctuations were driven by the aerobic respiratory activity of the vannamei shrimp during the night, leading to increased acidity, as well as the photosynthesis effect from surrounding plants during the day, causing acidity to decrease. The use of the aerator contributed to increased dissolved oxygen (DO), resulting in a reverse correlation with carbon dioxide levels and acidity. This indicated a slight increase in acidity, though not significantly. Monitoring the acidity levels from the first to the seventh day, as depicted in Figure 4.

3.2.2. Performance test of temperature using thermocouple type-k sensor

The water temperature of Gunung Anyar vannamei shrimp pond, as shown in Figure 5, displays fluctuating values, with the lowest recorded temperature at 23.59 °C and the highest at 38.32 °C. Temperature changes are not influenced by aerator usage but result from heat transfer, primarily the warmer ambient air affected by sunlight and the circulation of seawater into and out of the pond. The shrimp pond's water temperature starts rising at sunrise, peaking from (4 to 8 hours) or starting from 11:00 AM to 3:00 PM local time as indicated in Figure 5 then gradually decreases till early morning. Water quality is generally good, except from 11:00 AM to 3:00 PM when the temperature is excessively high, ranging from 28.44 °C to 38.32 °C.

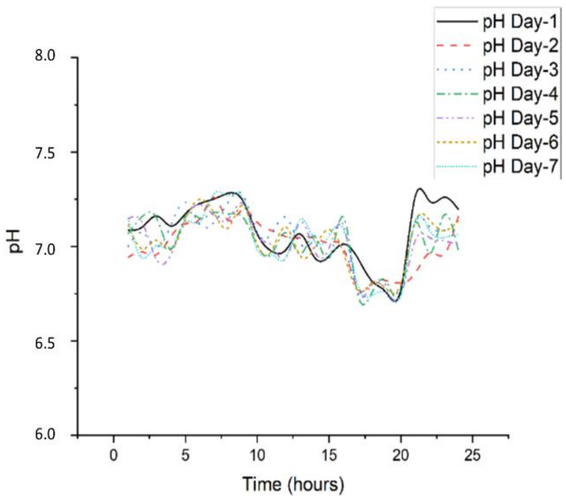


Figure 4. Performance test of pH during 7 days in 24 hours

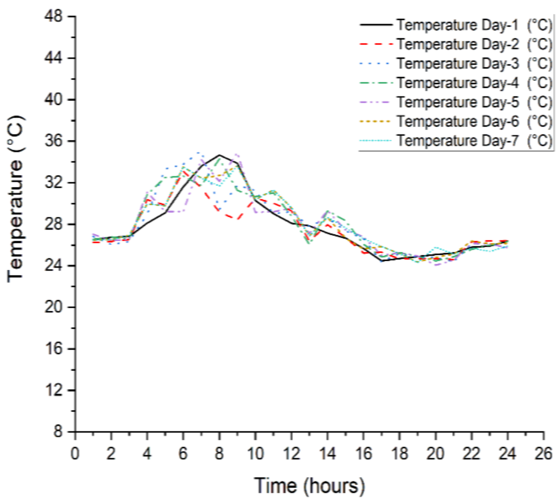


Figure 5. Performance test of temperature during 7 days in 24 hours

3.2.3. Performance test of total dissolved solid

The TDS values in Figure 6 obtained from a week-long test show readings within the TDS sensor range of 628.65 to 652.34 ppm. This indicates that the TDS levels in the Gunung Anyar vannamei shrimp are good and remain optimal for shrimp. Fluctuations in TDS readings stem from rock weathering and pond sediment, leading to increased TDS values. Aerator use also contributes to minor TDS reduction; however, the large cross-sectional area impeller powered by the VG45 DC motor does not reach high revolutions per minute (RPM) due to motor-impeller compatibility issues, resulting in slower rotations and fewer air bubbles. The sensor's placement beneath the aerator's float obstructs it from the impeller, preventing the direct impact of aerator-generated bubbles on water measurement.

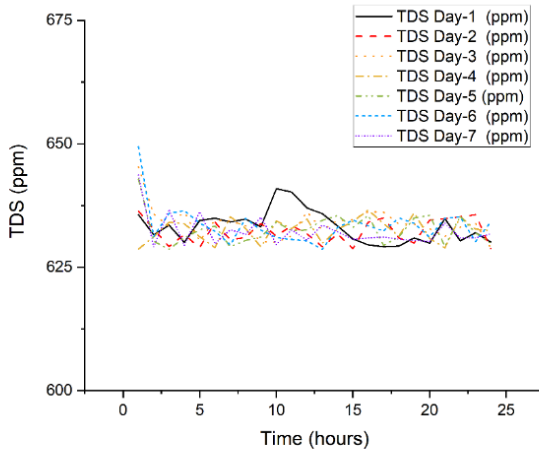


Figure 6. Performance test of TDS during 7 days in 24 hours

The average accuracy calculations for the GUI indicate the following sensor accuracy readings compared to the validator: 98.33% for the PH-4502C sensor, 98.93% for the type-K thermocouple sensor, and 96.99% for the TDS sensor. The average precision calculations yield the following sensor precision readings on the GUI compared to the validator: 100% for the pH sensor, 99.92% for the type-K thermocouple sensor, and 100% for the TDS sensor. However, when the average percentage error, accuracy, and precision values on Android and website GUI are calculated, they amount to an average percentage error of 1.43%, an accuracy of 98.57%. These results confirm that the integrated sensor system with the HMI aligns with the initial design criteria of error below 10%, and accuracy more than 90%. Our solar-based aerator is more effective compared to the other aerators from references [20] and [21], both use the solar-based aerator without a water quality monitoring system, meanwhile, our system has already integrated with the water quality monitoring system of the pond.

4. CONCLUSION

A water quality monitoring system based on acidity, temperature, and TDS is integrated into the solar-powered aeration system at Gunung Anyar vannamei shrimp pond. The vannamei shrimp pond monitoring system can be accessible through both the local plant's website GUI and real-time mobile phone Android application with an accuracy of 98.57% and an error of 1.43%. Data collection from July 17-24, 2023, shows acidity levels at 6.92 to 7.34, indicating poor conditions, while the temperature shows at 28.44 °C to 38.32 °C from 11:00 AM to 3:00 PM and TDS ranges between 628.65 to 652.34 ppm which is suitable for vannamei shrimp. Solar-powered aeration impacts TDS reduction and slight acidity increase due to aeration limitations in every two-minute operation affecting overall water quality.

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BIOGRAPHIES OF AUTHORS

I Putu Eka Widya Pratama received the M.Sc. degree (Master of Science) in applied physics from the Rheinisch-Westfaelische Technishe Hochschule University, Aachen, Germany, with the master thesis "Preparation and cleaning of tungsten tips mounted on quartz AFM sensors". He is a lecturer at the Instrumentation Engineering Department, Faculty of Vocational Studies, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. In addition, he is serving as International Liaison Officer of the Instrumentation Engineering Department. His research interests are in instrumentation and control, modular neural networks, nano sensors, and nanomaterials. He can be contacted at email: eka.widya@its.ac.id.

Friska Aprilia Kusuma received a bachelor's degree at the Department of Instrumentation Engineering, Faculty of Vocational. She contributed a lot to the Instrumentation and Control Laboratory, Department of Instrumentation Engineering. Her previous diploma thesis was entitled "Water quality monitoring system in vannamei shrimp pond, Gunung Anyar, Surabaya". She can be contacted at: friskaapriliakusuma@gmail.com.

Safira Firdaus Mujiyanti received an M.T. degree (Master of Engineering) in instrumentation engineering from engineering physics, Institut Teknologi Sepuluh Nopember, with a thesis "Control design optimization of gas processing plant with plantwide control method". She is a lecturer at the Instrumentation Engineering Department, Vocational Faculty, Institut Teknologi Sepuluh Nopember since 2020. Her research interests are in field instrumentation, process control, advanced process control, plantwide control, and hazard and operability study (HAZOPs). She can be contacted at email: safira.firdaus@its.ac.id.

Romana Schirhagl is a professor from the Department of Biomedical Engineering, University of Groningen, Netherlands. She received her doctoral degree from Vienna University, Austria with a thesis "Plastic immunoglobulins for the detection of bio-analytes with sensors". Her research interests are in the fields of biophysics, cell biology, and applied physics. Her expertise is in biophysics, diamond, nanotechnology, magnetometry, and equipment development. Also, she is the founder and director of Quantum sense (QTsense, www.qtsense.com). She can be contacted at r.schirhagl@umcg.nl.

Tepy Lindia Nanta a second-year student of Department of Instrumentation Engineering, at Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia. She is currently a laboratory assistant at Instrumentation and Control Laboratory. Her previous work entitled "IoT-integrated automatic monitoring and control system on vertical crab house to increase the living potential of mangrove crab at PT. Crab Crab Aquatic" has been published in Google Scholar. She can be contacted at email: tepylindiananta16@gmail.com.