Sustainable Aquaculture of Penaeus Monodon: IoT-Enhanced Automated Aeration System with Mobile Monitoring and Solar Panel Integration

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ABSTRACT

The demand for Penaeus Monodon shrimp in Indonesia is significantly high. However, this demand is not matched by a high success rate in harvests, primarily due to the low survival rate of Penaeus Monodon shrimp, which directly impacts production quantities. The survival rate of these shrimp is highly dependent on dissolved oxygen levels. The minimum threshold of dissolved oxygen required for Penaeus Monodon to respire is 5 ppm. This level serves as the minimum threshold to prevent respiratory collapse and subsequent mortality. Therefore, we developed an IoT-based automated aeration system that monitors dissolved oxygen levels in real-time to maintain levels above 5 ppm by supplying air bubbles through a venturi pipe. This system operates continuously and autonomously, enhancing sustainability, as it is powered by solar panels. Based on monitoring results, 90% of the trials indicated that the system could automatically activate and supply air bubbles to maintain dissolved oxygen levels within a safe threshold.

INTRODUCTION

Shrimp is one of the fishery commodities that is highly sought after and in demand by the community (Waiho *et al*, 2024). Shrimp ranks first in Indonesian fishery exports with a contribution of 14.13 percent of export volume and 42 percent of export value to the national fisheries trade balance. In 2008, Indonesia was the third largest frozen shrimp exporter in the world after Vietnam and Thailand (C Yolandika *et al*, 2022). One type of shrimp that is the main choice for Indonesian people to cultivate is the Penaeus Monodon shrimp. The reason for choosing this type of shrimp is because it has the advantage of rapid growth compared to other types of shrimp (Amalia *et al*, 2022). This needs to be considered because the survival rate of shrimp cultivation is not as high as other commodities (Coman *et al*, 2007). Dissolved oxygen is the strongest factor that causes shrimp to suffocate, which has an impact on decreasing harvest yields (Zaini *et al*, 2020).

The application of advanced technology such as an automatic aeration system supported by the Internet of Things (IoT) will have a better impact on improving harvests because this system will help pond farmers to carry out regular monitoring and immediately react if the monitoring results of the dissolved oxygen level are below the previously set threshold (Vinod *et al,* 2021). The system components will consist of several main components, namely solar panels as an energy source, controllers with WiFi modules, dissolved oxygen sensors, combustion engines, venturi pipes and mobile applications, for more details can be seen in Figure 1.

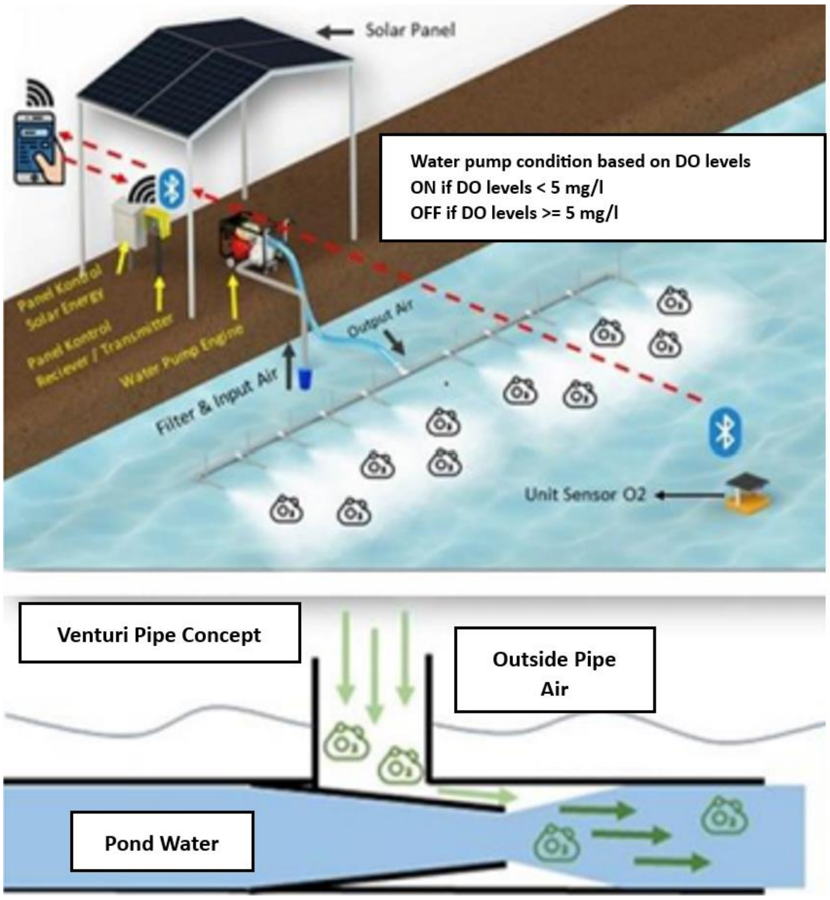

Figure 1. Pond Monitoring System Sketch

In figure 1 we can see that in flowing air to increase dissolved oxygen levels in strategic pond areas supported by a venturi pipe (Dange, 2023). The pipe that utilizes the thrust of air from around or outside the pipe that enters and is trapped then pushed by water that was previously sucked by the water pump so that it will create air bubbles that can maintain or increase dissolved oxygen levels if below the set threshold (Yadav *et al,* 2021). In this case, according to the experience of farmers in knowing the minimum limit of dissolved oxygen levels, researchers set a safe range of 5 mg/l, if below that value, the system will automatically turn on the water pump (Loyola *et al*, 2020).

RESEARCH METHOD

This system actually also relies on several sensors other than dissolved oxygen, including PH sensors and temperature sensors. However, the most influential on shrimp survival is dissolved oxygen, so that the water pump motor will react only from the dissolved oxygen level that has been set according to the safe threshold. The energy source in this system comes from solar panels that continue to supply power which is then stored in the battery. The electrical power will power several other components such as the controller and wifi module.

The system will be fully active if the sensor detects dissolved oxygen levels below the threshold, which is below 5 mg/l, so that the controller will be active and send a signal from the water surface area which is the location of the controller box and sensor module to be sent to the pump motor located in the pump house on the edge of the pond. After the motor receives a signal from the controller that the sensor level value has reached the safe threshold. When the signal has been received, the relay module will be active and distribute power to the water pump motor so that the motor will turn on and work to pump water to be distributed to the venturi pipe that has been placed on the water surface in the strategic pond area where the shrimp gather, in addition to the controller sending a signal to the pump motor, the controller will also send the sensing results to the monitoring application which can be viewed in real-time by the pond farmers.

This pond condition monitoring application has no limitations in distance and time of use, as long as the device is still on and has a good and stable internet network, then the pond farmers can monitor anytime and anywhere. In addition to monitoring, pond farmers can also turn on the motor directly through the application without waiting for the dissolved oxygen level to fall, if this is considered necessary by the pond farmers to be turned on. System details can be seen in figure 2.

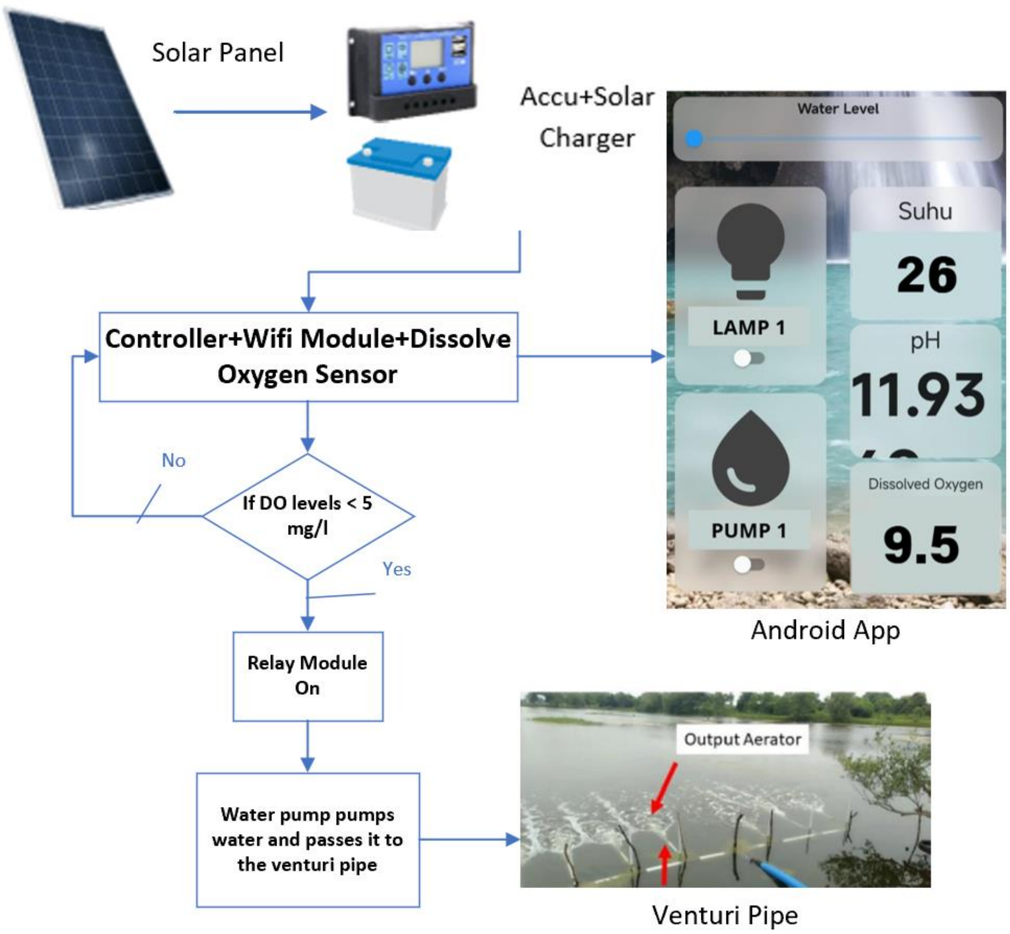

Figure 2. Pond Monitoring System Flowchart

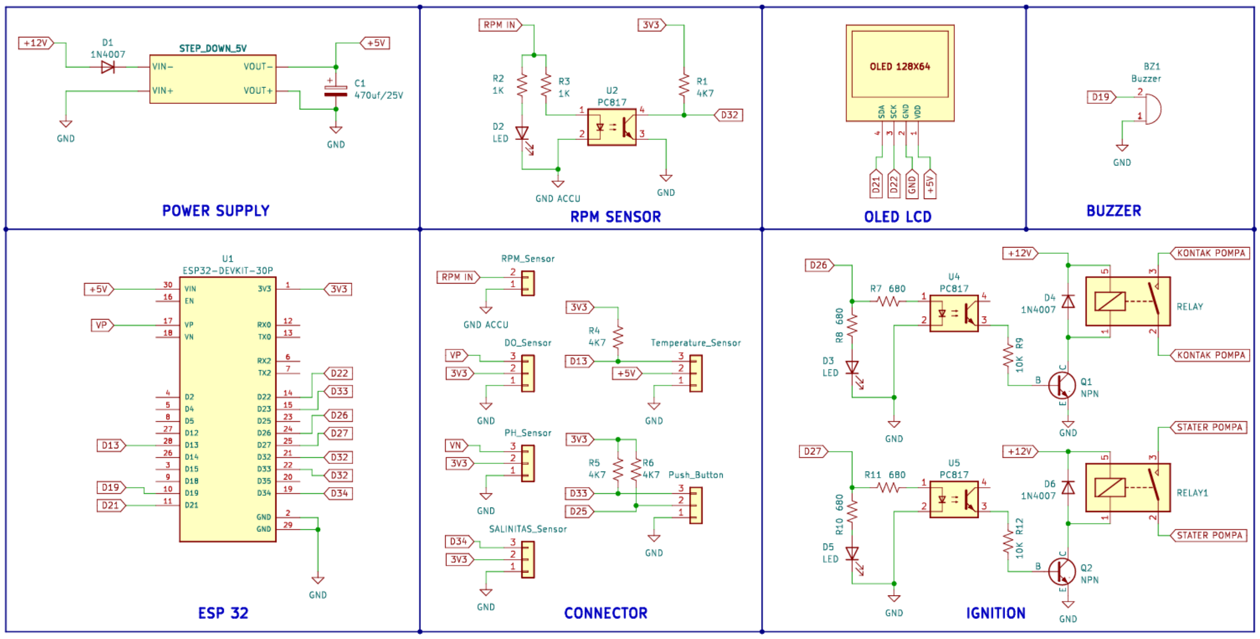

Figure 3. Pond Monitoring System Sketch

The circuit in the image is an IoT-based pond monitoring system designed using an ESP32 microcontroller to automatically monitor and control pond water quality parameters. The Power Supply module functions to reduce the voltage from a 12V input source to 5V using a step-down converter, ensuring a stable power supply for electronic components. The ESP32 microcontroller is the system control center, connecting various sensors and modules via I/O pins.

The Connector module includes the main sensors, such as an RPM sensor to monitor pump speed, a dissolved oxygen (DO) sensor to detect oxygen levels in the water, a temperature sensor to monitor water temperature, and a salinity sensor to measure salt levels. All of these sensors are connected via a connector to the ESP32 to read data in real time. Data from the sensors is processed and displayed via a 128x64 OLED LCD module, so users can see pond parameters directly. The system is also equipped with a buzzer as a sound warning device that will be activated if critical conditions are detected, such as a drastic decrease in oxygen levels or an extreme increase in temperature.

The Ignition module consists of a series of relays used to control the water pump. The relay is activated based on signals from the ESP32, which is triggered by reading certain parameters, such as turning on the pump when the oxygen level is below the threshold. In this section, indicator LEDs are used to provide visual information regarding the pump's operating status. The circuit also includes safety diodes to protect components from surges.

The system is designed to work efficiently with fast and responsive data processing. The combination of the ESP32 microcontroller, sensors, OLED display, and relays allows for smarter pond management, with automation that can improve water quality, optimize energy consumption, and maintain the stability of the pond ecosystem. In addition, this system can be expanded to support connectivity to IoT platforms, allowing remote monitoring via mobile device.

RESULTS AND DISCUSSION

This research was conducted for 24 hours starting from 07.00 until ending the next day at the same time by measuring several conditions such as the pH of the pond water, the surface temperature of the pond water, the dissolved oxygen levels and the reaction of the water pump when the oxygen level value reaches the predetermined threshold, for more details, see Table 1.

Table 1. Results of monitoring pond conditions

Time (24-Hour)	**PH**	*Temperature (^OC)*	*Dissolve Oxygen (mg/l)*	*Water Pump Condition (1=ON, 0=OFF)*
07.00	7.5	24	5,6	0
08.00	7,5	25	6,7	0
09.00	7,5	25	7,2	0
10.00	7,4	26	7,9	0
11.00	7,4	26	8,4	0
12.00	7,4	26	8,6	0
13.00	7,4	27	8,6	0
14.00	7,4	27	8,8	0
15.00	7,5	26	8,6	0
16.00	7,5	26	8,6	0
17.00	7,5	25	8,5	0
18.00	7,5	25	8,3	0
19.00	7,5	24	8,3	0
20.00	7,6	23	8	0
21.00	7,6	23	7,7	0
22.00	7,6	23	7,6	0
23.00	7,6	23	6,4	0
00.00	7,6	23	5,4	0
01.00	7,7	22	5	1
02.00	7,7	22	4,5	1
03.00	7,7	22	4,1	1
04.00	7,7	23	3,8	1
05.00	7,6	23	3,8	1
06.00	7,6	24	4,2	1
07.00	7,6	24	5,4	0

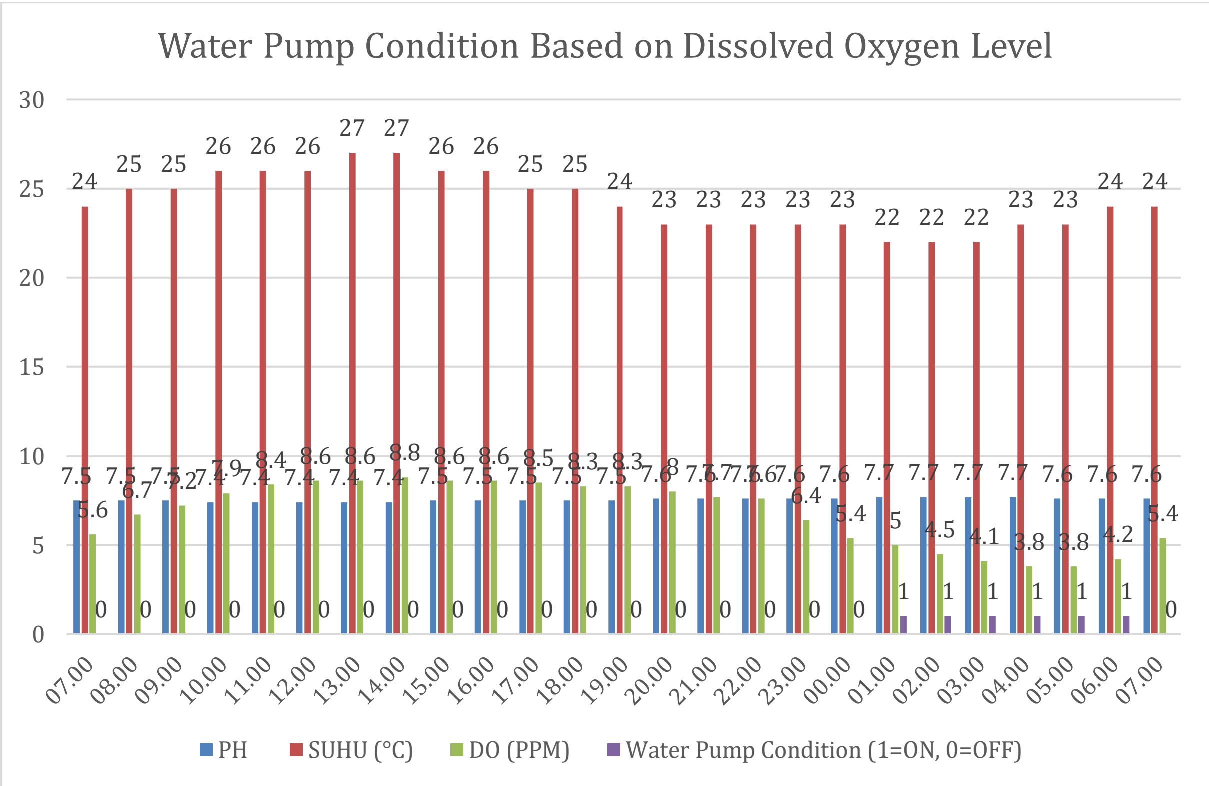

Figure 4. The relationship between water pump conditions and dissolved oxygen levels

Pond water management system using automatic pumps shows a close relationship between dissolved oxygen (DO) levels and water pump activation. In the morning to evening (07.00–19.00), DO levels are stable and high (5.6–8.8 mg/L), so the pump remains inactive because oxygen conditions are sufficient for the needs of pond biota. Photosynthetic activity by organisms such as phytoplankton is likely the main factor in maintaining DO during the day. However, at night to early morning (22.00–06.00), DO decreases drastically to a low of 3.8 mg/L due to minimal photosynthesis and increased oxygen consumption. As a result, the automatic pump is activated at 01.00 when DO drops below the critical threshold of 5 mg/L. Pump activation continues until DO increases again in the morning, indicating that this system is responsive to changes in water quality. In addition, water temperature ranges from 22–27°C and pH remains stable in the range of 7.4–7.7, reflecting an environment that supports the life of pond biota (Nandy *et al*, 2021). This system is effective in maintaining the balance of the pond ecosystem efficiently with pump activation only occurring at critical times.

CONCLUSION

The dissolved oxygen (DO) level-based water pump automation system has proven effective in maintaining pond water quality while increasing energy efficiency. Based on the data, the pump is active when DO drops to 4–4.5 ppm and turns off again after DO reaches an optimal level above 5 ppm, ensuring adequate water circulation without wasting energy. The DO level is stable during the day at around 7 ppm due to photosynthesis activity, but decreases at night and early morning due to increased oxygen consumption by pond biota. The water temperature is within a safe range (22–27°C) with a stable pH of 7.6–7.7, indicating a balanced ecosystem condition (Pantjara *et al*, 2021). With the pump operating only when needed, this system not only maintains the survival of pond biota but also supports ecological and economic operational sustainability, making it an ideal solution for IoT-based pond management.

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