Development of Real-Time Dissolved Oxygen Optimizer for Caged Fish Farm

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***Abstract*—This paper presents the development of real-time dissolved oxygen (DO) optimiser for caged fish farm. The prototype is for maintaining the DO level especially for sea basses, red snappers and groupers. An EZO-DO sensor senses the DO level, which then is sent to an Arduino microcontroller to process the data gathered. The prototype works by triggering the DO water pump if the DO level is less than 3 mg/L, and if the DO level is less than 4.5 mg/L, the paddle wheels will spin. The proposed DO optimiser is powered by a solar panel, hence it is suitable to be implemented in remote areas that are far from lagoon. The proposed DO optimiser is expected to maintain the DO level within 3 – 7 mg/L. Future work will focus on the system performance.**

Keywords—dissolved oxygen optimiser, caged fish farm, Arduino

I. Introduction

The continuous improvement of water quality variables for dissolved oxygen (DO) is significant to ensure the sustenance of commercial aquaculture industry. Maintaining the optimum water quality for fish growth can reduce the number of fish dead, hence increase the profit for firm farming [1]. Poor management of fish farming may result in the spread of viral diseases in fish and significant aquaculture losses [2]. Reduction in fish supply due to low DO, leading to fish kill, caused estimated losses of about RM 0.1 million in 2003, RM 2 million in 2007, RM 0.5 million in 2009, RM 0.02 million in 2012, and RM 0.02 million in 2014, as reported by Department of Fisheries (DOF) in Kelantan.

Previous studies have shown that increasing the DO contributes to more fish production. There are many techniques to increase the DO while reducing the water temperature. Authors in [3] implemented a microscopic bubble generating system to increase the DO level; for this case in Kusuura Bay, Japan. Three micro-bubble generators had been placed at a water depth between 3, 7, and 14 meters. The reliability of the system was determined based on the maximum concentrations, which were 6.51 mg/L at 3 meters depth, and 6.76 mg/L at 7 meters and 14 meters depth, from the horizontal distribution of DO. When the concept was changed to vertical distribution, the DO level decreased about 1 mg/L by each depth. Authors in [4] implemented an embedded microcontroller (MSP430 series) to monitor the DO, temperature, and pH level of the fish farm aquaculture environment. The novelty of the system was indicated by a wireless sensor using ZigBee. Besides, the reading measured could be monitored using mobile phone, developed using Android SDK software. However, the authors did not implement the proposed system in real application, therefore the reliability of the system cannot be obtained.

In studying the growth production of fish in Mymensingh, Bangladesh, authors in [5] conducted an experiment at two treated tilapia ponds. One pond was treated by aeration through using a blower, while the other pond was non-aerated. Aeration was done three times a day for 3 hours, and the measurements were taken from May to September 2016. The outcome revealed that there was slightly higher DO, with an average of 5 mg/L in the aerated pond, compared to the non-aerated pond. In addition, the temperature in the aerated pond was slightly lower than the non-aerated pond with a difference of 0.24^{0}C. In Ibadan, Nigeria, the authors in [6] measured DO at a catfish farm during dry and wet seasons. The results indicated 8.01 mg/L of DO with temperature of 24^{0}C during dry season and DO value of 8.33 mg/L with temperature of 22^{0}C during the wet season. In relation to Malaysian season, heavy rain may contribute to increase of DO level, but for cases like flood in certain states (Kuala Lumpur, Kedah, Penang and Perlis) that normally happens from December to January [7], the contaminated water may reduce the DO.

Sung et al [8] made improvement on wireless monitoring system as reported in [4] by enhancing the solar system. Improvement in graphical user interface (GUI) was made, by presenting measurement in graph to ease users in understanding the trend, especially DO and temperature. The data measured was stored in Cloud storage, and any user is able to retrieve the data in real-time. The benefit of using solar panel system is that the system can be applied in remote areas, which is beneficial for fish farms that are usually located in rural area. For an early prototype, authors in [9] developed a Wi-Fi wireless transfer automation fish farming using embedded system. Sensors were used to monitor pH, temperature, and quality of water. The authors found that when the pH value was less than 4.5, the fish died. To prevent this, the proposed system automatically triggered the DC motor and aerator to ensure DO kept optimum. However, the reliability of the system was not tested since it was still a prototype.

This study is focused on caged fish farm at an estuary in Tumpat, north-east of Peninsula Malaysia. The farm supplies fish like sea basses, red snappers, and groupers for local and imports. The proposed system is supplied with 24V solar panel, and the energy is stored inside a battery. An EZO-DO sensor is used to measure the DO level of fish farm. The pump that stores the DO water as well as paddles is triggered when the sensor detects DO level less than 3 mg/L. The use of paddles is to increase and keep the DO level to be within 3 to 7 mg/L since it is recommended for caged fish production in Malaysia [10]. The effectiveness of this method has been verified, as in the monitoring results disclosed.

II. METHOD TO INCREASE DISSOLVED OXYGEN

Dissolved oxygen is important for optimum water quality for caged fish [11]. The level of dissolved oxygen in the water can be increased by several ways, either by using aerator, mini bubble injection, or chemical compound [12]. The most basic method is by installing a mechanical water splash to regulate the water frequently and periodically, controlled by a simple timer. Mini bubbles which are rich in oxygen can also be injected into water in a periodically manner.

The aforementioned methods are the most basic ways to increase the dissolved oxygen level in the pond/fish cage. To increase the efficiency, usually there are more than one mechanical water splash installed in the fish cage. However, there are some of the drawbacks with these mechanisms; one of which is the lack of monitoring system used to measure the level of dissolved oxygen over time. This kind of monitoring system is important especially when there is a sudden depletion of dissolved oxygen of pollution, algae bloom, or other reasons [13]. Besides that, motor used to turn the water splash is energy consuming [14]. Therefore, a new renewable energy technology can be integrated with this basic method. Fig. 1 shows the flow diagram of proposed design system to control the DO level in caged fish farm industry.

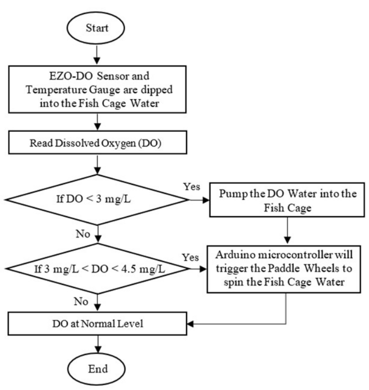

Fig. 1. Flowchart of the proposed design system

A. *Design of Solar Powered Automatic Dissolved Oxygen Optimiser for Caged Fish Farm Industry*

Fig. 2 shows the design of solar powered automatic dissolved oxygen optimiser for caged fish farm industry. The EZO-DO sensor and temperature gauge are dipped into the fish cage water. Supplying DO from aerated water flowing down from two aeration tanks, the DO optimiser can be stationed far into the lagoon since it is solar powered. If the sensor indicates that DO concentration in the cage water is below 3 mg, an extra DO water will be pumped/supplied. Subsequent low DO concentration after the DO water infiltration will trigger the paddle wheels to spin until the DO reaches normal level.

An optimiser has been designed to adapt to the present condition at the estuary as well as to optimise the DO, within level of 3 to 7 mg/L to avoid hypoxic or oversaturation. The present estuary condition has issues such as fluctuating tides and flood which make it difficult to control the DO level, no device is available to continuously monitor and control the DO in caged fish farm, mud flooding the cages due to changing tides and also covering fish gill which suffocate them from breathing, as well as clogging of the barnacles during flood.

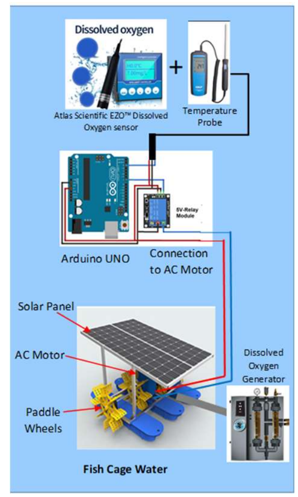

Fig. 2. Design of solar powered automatic dissolved oxygen optimiser for caged fish farm industry

As shown in Fig. 3, the proposed solar powered automatic fish DO optimiser has components like solar panel, AC motor, Arduino UNO, relay, battery, and inverter. The working procedure starts with solar panel cable connected to the 2 terminals of solar panel, then the main switch is turned on, followed by switching on of the voltmeter and inverter switches. Two 12 V batteries are used to store the energy to ensure the continuity of supply. This system is connected to 240 VAC output terminals. Then, the mode switch is turned on to measure both solar panel and battery voltages.

The Atlas scientific EZO-DO sensor, which is a galvanic dissolved oxygen probe, consists of a polytetrafluoroethylene membrane, an anode bathed in an electrolyte, and a cathode [15]. Oxygen molecules defuse through the probes membrane at a constant rate. Once the oxygen molecules have crossed the membrane, they are reduced at the cathode and a small voltage is produced. If no oxygen molecule is present, the probe will determine output as 0 mV. As the oxygen increases, so does the mV output from the probe. Each probe will output different voltage in the presence of oxygen. The only thing that is constant is 0mV = 0 oxygen.

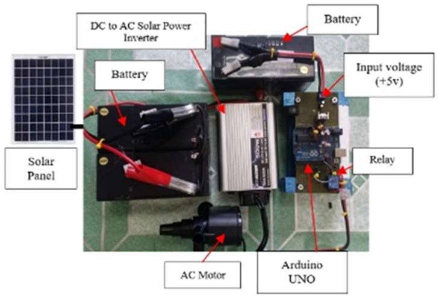

Fig. 3. Electronic apparatus for the proposed system

The sensor is dipped into the water where there are visible dead fish. If the system detects DO level with reading below 3 mg/L, it will trigger the upward water pump to pump water up into the upper aeration tank. To ensure the reliability of measurements, the DO sensor was calibrated by using a 0 mg/L DO solution. The value measured by a sensor should indicate almost similar value. The water in the upper tank will flow down into a lower aeration tank through series of physical obstacles to create rapid-like effects to supply oxygen into the water, which flows into the lower aeration tank. Then, dissolved oxygenated water is pumped into a network of water pipes to distribute the DO water evenly throughout the whole cage complex. If DO level remains below 3 mg/L after 20 minutes of DO water pumping into the cage water, the sensor system will trigger the paddle wheels to spin for better aeration for the fish. The fish cage can be moved from one location to another to get a better position for DO supply in case of need or in case of flood in the area, since it is solar powered that can generate its own power anywhere.

III. Proposed Do Optimiser

Based on literature, the DO indication differs by country, thus different value. As shown in Table I, the optimum DO in Malaysia is between 3 to 7 mg/L. Meanwhile, countries like Philippines and Australia require DO more than 5 mg/L for the fish to survive. If the value of DO is too low, the fish and other aquatic organisms cannot survive. Temperature also plays a vital role in maintaining the DO, by means the lower the temperature, the higher oxygen content it can hold [16]. In accordance, the temperature inside caged fish farm in Malaysia should be kept within 20 to 30 0C.

TABLE I. Optimised Parameters for Cages Fish Production in Different Countries

Water Quality Parameters	Temperature (^0C)	Dissolved Oxygen (mg/L)
India [17]	21 - 33	4.0 – 10.0
Australia [18]	-	> 5.0
The Philippines [18]	-	5.0
Malaysia [10]	Normal + 2	3.0 – 7.0

The proposed DO optimiser as shown in Fig. 4 is significant for the fishing industry since it can help to regulate the oxygen quality in estuary area especially at caged fish farm. The proposed system can be stationed far into the lagoon since it is fully solar powered. It is not only capable of solving the low DO problem in the farm fish cage, but also improve water clarity. Consequently, the use of DO optimiser may multiply the income of caged fish farmers. In addition to intelligent and efficient DO control, the proposed system can reduce the mud from covering fish's gill. Besides its ability to reduce barnacles from clogging the cages, lowering production and maintenance cost, the DO optimiser may give a significant impact on the social and economic development of the fishing industry, in addition to ensuring environmental sustainability in the estuary areas.

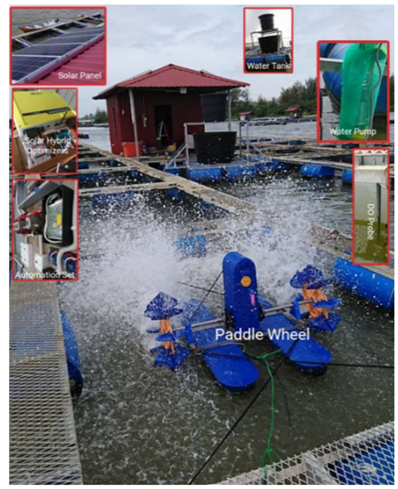

Fig. 4. Dissolved oxygen optimiser prototype in full operation due to low DO concentration

Technically, with the proposed DO optimiser, the DO level could be maintained more than 3 mg/L. The proposed system operates automatically based on threshold value (3 mg/L), by means the paddle wheels will start spin and the DO water is pumped to the farm fish cage if the DO level is less than that. Last but not least, there are some improvements that can be added to the prototype. The author discovered that the aeration tanks were not up to the original design to produce water filled with high concentration of dissolved oxygen due to its high production cost. Therefore, the upper tank can be raised to optimum to maximize dissolved oxygen level into the poured water. Also, without a proper shield, this might lead to a lot of DO water wastage. Secondly, the lower tank had to be filled with needle-like pokers pointing upwards to break the poured water to create rapid-like effect in the effort to maximize oxygen getting into the water.

IV. Conclusion

The proposed DO optimiser functions to stabilize the dissolved oxygen (DO) level in the water of caged fish farm. An EZO-DO sensor is placed deep inside the water and the value is recorded for 24 hours daily. The proposed DO optimiser developed will automatically trigger the pump from the stored DO water as well as rotate the paddles if the DO value drops to less than 3 mg/L. From the outcomes obtained, the proposed prototype is indeed capable to maintain the DO value to more than 3 mg/L. Accordingly, the DO will rise to the optimised value (within 3 to 7 mg/L), hence the percentage of dead fish can be reduced.

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