

Original Article

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Monitoring pH And Turbidity of Crayfish Pond Using Website and Automation Controlling Using Sugeno Fuzzy Logic Method

Ading Atma Gamilang, Eko Satria, Melany Febrina *

Master's Program in Physics, Department of Physics, Institut Teknologi Sumatera, Lampung Selatan 35365, Indonesia

* Corresponding E-mail: melany.febrina@fi.itera.ac.id

Abstract: Crayfish, particularly *Cherax Quadricarinatus*, hold significant potential for aquaculture due to their high market value and substantial demand both domestically and internationally. The growth of freshwater crayfish is heavily influenced by the pond environment. Several environmental factors affect this growth, including water turbidity, pH, dissolved oxygen, temperature, and ammonia levels. This study focuses on monitoring water turbidity and pH using DFRobot Turbidity SEN0189 and PH-4502C sensors, and displaying the results on a monitoring website. Additionally, a pump filter and aerator are employed as actuators for control. The control method used is Sugeno Fuzzy Logic, which makes control system decisions when sensors detect pH and turbidity values outside the optimal range for crayfish ponds: 6-8 for pH and 5-25 NTU for turbidity. The Sugeno Fuzzy Logic method used has inputs based on sensor readings, each with three membership degrees; for pH, Acid (0-6.5), Neutral (6-8), and Base (7.5-14); and for turbidity, Clear (0-5 NTU), Turbid (4-15 NTU), and Very Turbid (14-25 NTU). The outputs control the pump filter and aerator, with two membership degrees: Off, On, and On-Extended. The sensors have successfully measured pond turbidity with an error of 4.76% and pH with an error of 0.9%. The control system has been successfully implemented, with the pump filter and aerator activating in response to measured conditions in the crayfish pond.

Keywords: Crayfish, Monitoring, Control, Fuzzy Logic, Internet of Things.

Introduction

The freshwater crayfish species *Cherax* is a high-value aquaculture commodity with increasing market demand. However, farming this species presents specific challenges, particularly in maintaining stable pond water quality. Optimal water conditions are crucial to ensure the growth and survival of crayfish [1]. Parameters such as temperature (24-31°C), pH (6-8), turbidity (5-25 NTU), dissolved oxygen (6-8 mg/L), and ammonia levels (<1.2 ppm) must be maintained within appropriate ranges. Suboptimal water quality can induce stress in crayfish, reduce growth rates, and even cause mass mortality, leading to significant economic losses for farmers [2].

This study aims to design a monitoring and control system for water quality in *Cherax* ponds using two main sensors: the SEN0189 turbidity sensor to measure water turbidity, and the PH-4502C sensor to measure water acidity [3] [4] [5]. High turbidity can hinder crayfish respiration and reduce oxygen absorption efficiency [6].

Meanwhile, an imbalanced pH can affect crayfish metabolism, potentially decreasing their resistance and growth [7]. The sensors are connected to a MegaPRO 2560 microcontroller with an additional NodeMCU 8266 module for data transmission to a database. The system is integrated with two relays for controlling the aerator and water filter, which automatically maintain stable water quality. The aerator increases dissolved oxygen levels in the water, while the water filter maintains turbidity at an optimal level. The control system is implemented using Sugeno fuzzy logic to determine the optimal response to changing water conditions. The water quality monitoring system is accessible through a dedicated website.

The implementation of this monitoring and control system is expected to create ideal water conditions for the growth and development of *Cherax* crayfish, thereby reducing mortality risks and enhancing aquaculture productivity.



Method

In the control method used to optimize crayfish pond water conditions, Sugeno Fuzzy Logic is applied. The sensor measurements and actuator responses are displayed on a simple monitoring website. The block diagram of the system used is shown in **Figure 1**.

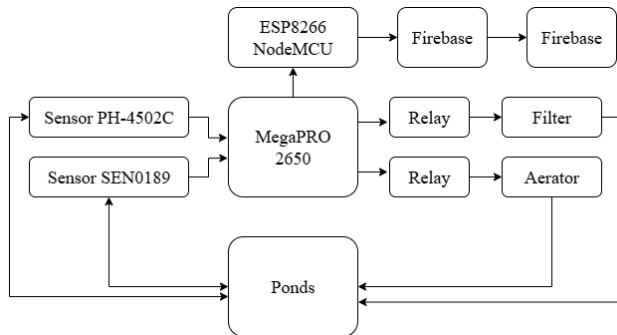


Figure 1. System block diagram.

The device is powered by a 12V power supply, with the voltage regulated to 5V using a voltage regulator. Capacitors are added to ensure a stable voltage supply for the microcontroller, sensors, and actuators.

Sugeno Fuzzy Logic

Fuzzy Logic is employed as a basic artificial intelligence system for decision-making in optimizing water conditions in crayfish ponds. This study uses Sugeno fuzzy logic, which generates outputs as linear functions or constants [8]. This facilitates integration with control systems that require quick, precise responses, such as hardware control systems. **Table 1** shows the fuzzy sets for input and output in the crayfish pond control system.

Table 1. Fuzzy Set Division for Input and Output.

Function	Variable	Fuzzy Set	Parameter
Input	pH	Acid	0 – 6,5
		Neutral	6 – 8
		Base	7,5 – 14
	Turbidity	Clean	0 – 5 NTU
		Turbid	4 – 15 NTU
		Very Turbid	14 – 25 NTU
Output	Aerator	OFF	0
		ON	0,5
		ON EXTENDED	1
	Filter	OFF	0
		ON	0,5
		ON EXTENDED	1

Trapezoidal and triangular membership functions will be used to model pH and turbidity values.

In Fuzzy Logic, we need fuzzy rules as a reference for the desired control system. **Table 2** shows the fuzzy rules used in this study.

Table 2. Fuzzy rules in the control system.

pH	Turbidity	Aerator	Filter
Acid	Clean	ON	ON
Neutral	Clean	OFF	OFF
Base	Clean	ON	ON
Acid	Turbid	ON EXTENDED	ON
Acid	Very Turbid	ON EXTENDED	ON EXTENDED
Base	Turbid	OFF	ON
Base	Very Turbid	OFF	ON EXTENDED
Neutral	Turbid	ON EXTENDED	ON
Neutral	Very Turbid	ON EXTENDED	ON EXTENDED

Based on the formulated rules, nine rules will be used in the defuzzification process to obtain the output constant value.

Results And Discussion

The implementation of the monitoring and control system, based on the previously designed setup, uses a single 12V 12A power supply. **Table 3** shows the total power consumption of the sensors and actuators used.

Table 3. Total power consumption of the devices used.

Input	Voltage (V)	Current (mA) Max	PIN	Note
MegaPRO 2650	5	220	VIN	-
ESP8266	5	200	VIN	-
PH4502C	5	10	A1	-
SEN0189	5	40	A2	-
Total		470		
Output	Voltage (V)	Current (mA) Max	PIN	Keterangan
Relay 1	5	100	D32	Aerator
Relay 2	5	100	D33	Pump Filter
Total		200		

Calibration Results of the SEN0189 Sensor

The SEN0189 turbidity sensor measures light scattering from suspended particles and is calibrated by comparing its ADC values to those of a Velp TB1 turbidity meter in NTU units. The measurement process is presented in **Figure 2**.

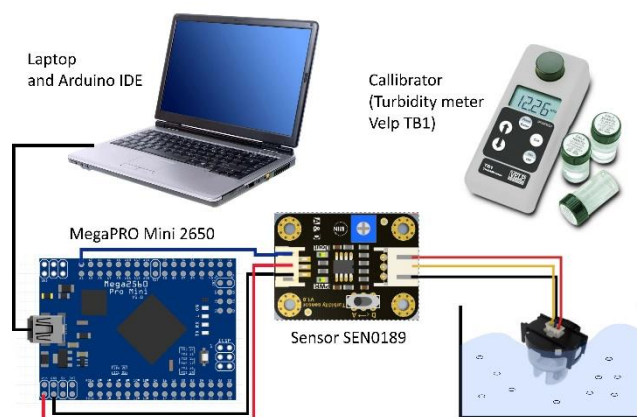


Figure 2. Turbidity sensor measurement process.

Ten solutions with different turbidity levels were prepared, with NTU values of 0.84; 7.14; 8.53; 11.82; 13.23; 16.2; 19.4; 20.9; 28.8; and 33. The ADC values were compared with the known NTU values and are shown in **Table 4**.

Table 4. SEN0189 sensor calibrating results.

	Kekeruhan (NTU)	ADC
Sample 1	0,84	901
Sample 2	7,14	887
Sample 3	8,53	882
Sample 4	11,82	867
Sample 5	13,23	859
Sample 6	16,2	855
Sample 7	19,4	846
Sample 8	20,9	837
Sample 9	28,8	821
Sample 10	33	805

The graph in **Figure 3** shows a negative linear correlation between turbidity and the sensor's ADC value. As the water turbidity decreases, the ADC value increases. This is consistent with the working principle of the SEN0189 sensor, in which the photodiode captures less light as turbidity increases. The obtained transfer function is $y =$

$295.78671 - 0.32687 x$, where y represents turbidity and x represents the ADC value. This function is integrated into the microcontroller's turbidity-reading program. After calibration, the sensor was tested with five random solutions and compared to the Velp TB1 turbidity meter (**Table 5**).

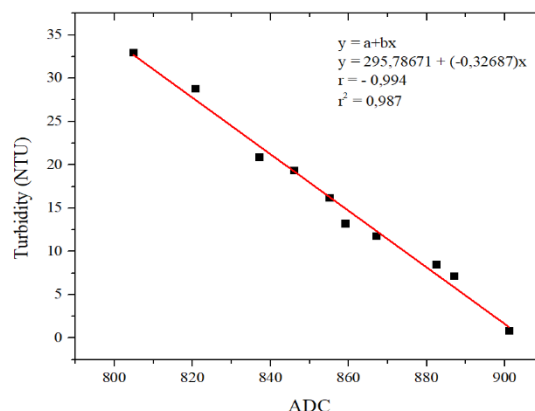


Figure 3. Graph of the linear transfer function for the Turbidity SEN0189 sensor and the measured NTU values.

Table 5. SEN0189 sensor testing results.

	SEN0189 (NTU)	Turbidity-meter (NTU)	Error (%)
Sample 1	0,94	0,84	11,9
Sample 2	7,60	7,14	6,44
Sample 3	24,72	24,2	2,15
Sample 4	19,81	19,3	2,64
Sample 5	18,74	18,29	2,47
	$\bar{x}$		5,1

The results in **Table 5** show an average deviation of 0.41 NTU and an error of 5.1%, indicating that the SEN0189 sensor is sufficiently accurate in measuring water turbidity.

Calibration Results of the PH-4502C Sensor

The calibration of the PH4502C sensor was carried out by measuring ten pH solution samples prepared from buffer solutions of pH 4.01; 6.86; and 9.18, which were then varied using pH-Up and pH-Down solutions to obtain ten different pH levels: 2.06; 3.10; 4.00; 6.86; 8.05; 9.18; 10.20; 11.04; 12.03; and 13 (**Table 6**). The measurement process is presented in **Figure 3**.

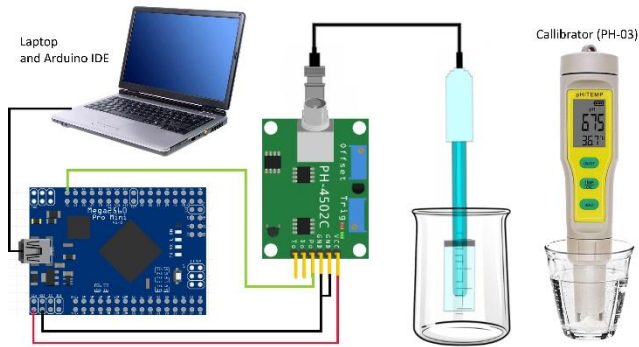


Figure 3. PH-4502C sensor measurement process.

Each solution was measured with the PH4502C sensor and compared with measurements obtained with a pen-type pH meter (PH-03). The sensor was directly immersed in the solution, and the ADC values were read via the Arduino IDE serial monitor. The ADC values were compared with the known pH values and are shown in Table 6.

Table 6. PH-4502C sensor calibrating results.

	PH	ADC
Sample 1	2,06	998
Sample 2	3,1	969
Sample 3	4	927
Sample 4	6,68	848
Sample 5	8,05	838
Sample 6	9,18	804
Sample 7	10,2	800
Sample 8	11,04	776
Sample 9	12,03	745
Sample 10	13	740

The measurement data were then used to construct a linear relationship graph between the ADC value (x) and the pH value (y), as shown in Figure 4, resulting in the transfer function $y = 43.209 - 0.0417x$. This negative linear correlation indicates that the lower the pH (more acidic), the higher the measured ADC value. This principle is consistent with the sensor's characteristics, which employ a glass electrode sensitive to hydrogen ions (H^+) and a reference electrode.

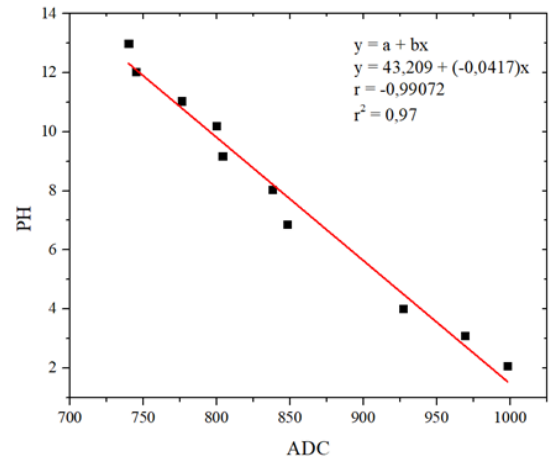


Figure 4. Graph of the linear transfer function for the PH4502C sensor and the measured pH values.

After calibration, the sensor was tested with five samples and compared to the PH-03 pH meter. Table 7 shows an average deviation of 0.08 and an error of 0.9%, which is sufficiently accurate to maintain the pH of the crayfish pond within the range of 6-8.

Table 7. PH-4502C sensor testing results.

	pH-Meter	Sensor pH	Error (%)
Sample 1	2,6	2,58	0,77
Sample 2	5,27	5,22	0,95
Sample 3	7,05	7,07	0,28
Sample 4	12,73	12,49	1,89
Sample 5	9,83	9,89	0,61
	$\bar{x}$		0,90

Turbidity Control System Testing

In the turbidity control test, the relay activates the pump to direct water to the filter when the turbidity sensor detects levels above 25 NTU. The filter used is a simplified version of a filtration medium with four layers: sponge, zeolite, activated carbon, and cotton [9]. When water turbidity exceeds 25 NTU, the pump is activated, and the filtration process reduces turbidity to 15 NTU within 20 minutes (Figure 5). This duration is used as a reference for the filter activation time in the fuzzy control system for the "Long On" condition or when the output value is 1.

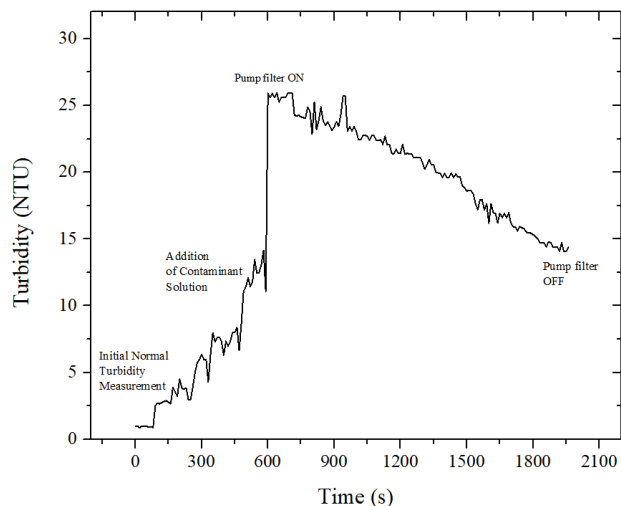


Figure 5. Turbidity control test results.

pH Control System Testing

In the pH control system test, the filter and aerator activate when the measured pH value falls outside the normal range for crayfish pond water conditions (6-8). **Table 8** presents the results of the pH control system testing.

Table 8. pH control test results.

pH Value	Aerator and Filter
4	ON
6,86	OFF
9,18	ON

Overall System Testing

After calibration and control system testing, the overall system was tested. The MegaPRO 2650 microcontroller was programmed to read the SEN0189 and PH-4502C sensors and to make decisions using the Sugeno fuzzy logic method. **Table 9** shows the results of the sensor measurements and actuator values obtained.

Table 9. Overall testing results of the monitoring and control system.

Input	
Turbidity	4.97 NTU
pH	7.14
Output	
Aerator	0 (OFF)
Filter	0.47 (ON)

The pH reading indicated a neutral condition of 7.14, and the turbidity value was 4.97 NTU. The output value determined the duration of relay actuator activation.

$$\mu_{\text{Aerator}} = 0 \times 20 \text{ Minutes} = 0 \text{ Minutes}$$

$$\mu_{\text{Filter}} = 0.47 \times 20 \text{ Minutes} = 9,4 \text{ Minutes}$$

The sensor and actuator data were then transmitted to the NodeMCU ESP8266, which forwarded them to Firebase. The serial communication between the MegaPRO 2650 and the ESP8266 used serial3 at 9600 baud. **Figure 6** shows the data successfully transmitted to the NodeMCU.

```
Received Data: 7.14,4.97,0.00,0.47
ACK
Checksum verified, processing data...
Data sent to Firebase successfully
```

Figure 6. Arduino IDE serial monitor display for data reception on NodeMCU ESP8266.

The data were then sent to Firebase via the Internet, and **Figure 7** shows the data received on Firebase.



Figure 7. Data is received by the Firebase database in real-time.

The data stored in the database is then displayed on the website. **Figure 8** shows the monitoring website for the crayfish pond conditions.

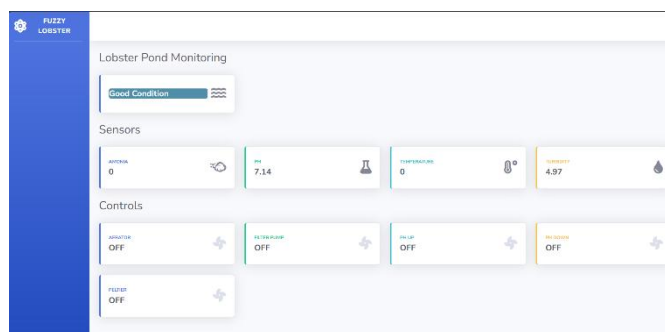


Figure 8. Website interface for monitoring the crayfish pond.

Conclusions

This study successfully developed a water-quality monitoring and control system for freshwater crayfish ponds using the PH-4502C sensor, the SEN0189 turbidity sensor, and the Sugeno Fuzzy Logic method, integrated with the MegaPRO 2560 microcontroller and the ESP8266 module. Calibration results indicated that the sensors used have satisfactory accuracy, with error rates of 0.9% for the PH4502C sensor and 5.1% for the SEN0189 sensor. The system effectively maintained pH and turbidity within optimal ranges: pH between 6 and 8 and turbidity below 25 NTU. The implementation of the Sugeno Fuzzy Logic method provided an accurate control response for managing the filter pump and aerator to maintain pond stability. Additionally, real-time monitoring of crayfish pond conditions can be performed through a dedicated website. This system has the potential to enhance crayfish growth and reduce the risk of farming failure caused by poor water quality.

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