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Water quality control on fish aquarium using Fuzzy Logic method

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ABSTRACT

Indonesia, as an archipelagic country, boasts abundant fishery resources. The effective development of these resources has the potential to yield sustainable benefits, contributing to the prosperity of its people. Maintaining water quality plays a pivotal role in advancing fish farming practices, hence the necessity for water quality analysis. This study endeavors to design and construct a control system tailored for freshwater fish aquariums, employing Fuzzy logic methods. This system incorporates pH, temperature, and total dissolved solid sensors, aiming to regulate the duration of the water pump and heater operation based on Fuzzy-derived decisions when the setpoint values for pH, temperature, and TDS are not met. Analysis of water quality measurements demonstrates the tool's capability to achieve a pH measurement accuracy of 99.17%, temperature accuracy of 99.10%, and TDS accuracy of 99.44%.

1. Introduction

Indonesia, an archipelagic nation, possesses extensive fisheries resources. If these resources are effectively developed, they can yield maximum sustainable benefits for the welfare of the Indonesian populace. Indonesia hosts a notable presence of eels, housing approximately six species: Anguilla bicolor, Anguilla marmorata, Anguilla celebensis, Anguilla ancentralis, Anguilla borneensis, and Anguilla bicolor pacifica. These diverse eel species are found across the waters of West Sumatra, Java, Bali, NTB, NTT, Sulawesi, East Kalimantan, Maluku, and Papua [1].

The life cycle of eels typically involves five stages: larvae, eel seeds, pigmented eels, young eels, and adult eels. During the larval phase, which resembles a transparent leaf, they exhibit high adaptability and live planktonically in the open sea. These larvae actively migrate to estuaries with lower salinity and metamorphose into eel seeds, measuring an average length of 5 to 7 cm and weighing around 0.17 g to 0.21 g. The eel fry then journeys upstream as pigmented eels (9 to 11 cm in length and 2.8 to 3.2 g in weight) for 4 to 8 months post-hatching, developing into young eels with a body length of approximately 40 cm in freshwater habitats. As they transform into adult eels, they become prepared for spawning and eventually migrate back into the sea [2].

Temperature is a crucial physical parameter, utilized for measurement and control across various applications. It serves as an indicator that elucidates environmental conditions, making it an essential factor in any habitat. Deviations from the ideal temperature range can significantly impact organisms, particularly aquatic life. Understanding the suitable temperature for eel breeding is imperative. Water temperature, influenced by factors like season, location, and water depth, plays a pivotal role. Optimal freshwater fish farming typically thrives within the temperature range of 25°C to 32°C [3]. For catfish farming, the growth conditions are optimum at temperatures between 26°C to 30°C [4]. Tilapia cultivation flourishes within the temperature range of 25°C to 30°C [5]. Eel cultivation finds its ideal temperature range between 28°C to 32°C. Elevated water temperatures, even by 10°C, promote increased growth of bacteria responsible for organic matter decomposition. This rise affects bacterial

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enzyme activity, consequently accelerating bacterial metabolism. Hence, nitrogen decomposition processes occur more rapidly in higher temperature conditions [6].

The pH serves as an indicator for measuring the acidity or alkalinity level within a solution, ranging from 0 to 14, with pH 7 denoting neutrality. A pH below 7 signals acidity, while a pH above 7 denotes alkalinity. Essentially, pH gauges the balance between free hydrogen ions and hydroxide ions in water. Increased free hydrogen ions lead to acidity, whereas higher concentrations of free hydroxide ions result in alkalinity. Chemical presence in water can influence pH conditions, making it a crucial indicator for chemical shifts in water dynamics [7].

Total Dissolved Solids (TDS) represent the solubility of solids in water, encompassing the water's capacity to dissolve solid substances in the form of ions, compounds, or colloids. Assessing the safety of water consumption relies significantly on the concentration of dissolved solids or minerals within the water. Examples of minerals soluble in water include limestone, iron, lead, magnesium, copper, sodium, chloride, chlorine, and various other elements [8].

A sensor serves as a component facilitating the conversion of physical phenomena into electrical signals for devices. Essentially, all sensors function on a similar principle, generating analog signals representing electrical currents with specific voltage values. To enable digital processing, these signals must undergo conversion into a digital format [9]. For monitoring aquarium water quality, an automated system was developed using Arduino as a microcontroller, alongside pH, temperature, and TDS sensors. Arduino IDE controls several components, including pH sensors, temperature sensors, and TDS sensors [10].

A pH meter sensor measures the acidity or alkalinity level of a liquid/solution. The sensor probe, featuring glass electrodes, contains an HCL solution at its end. This probe measures the $H3O+$ ion value in a solution, enabling the determination of the solution's pH level [11]. The temperature sensor converts heat quantities into electrical quantities to detect temperature changes in objects. A thermistor, a type of resistance, significantly alters its resistance value with temperature fluctuations. Thermistors come in two types: positive temperature coefficient (PTC) and negative temperature coefficient (NTC). PTC thermistors exhibit increased resistance with rising temperatures, whereas NTC thermistors display decreased resistance with increasing temperatures [12]. The TDS sensor operates based on the conductivity principle, featuring two probes immersed in a solution with an applied electrical potential difference (typically a sinusoidal form). Consequently, an electric current flow through the plates, and the solution's conductance remains proportional to the ion concentration within the solution [13].

A microcontroller is a type of integrated microprocessor chip that serves as the core or brain of a device. The development of logic and algorithms for specific purposes in microcontrollers is carried out using programming languages such as Assembler, C, or C++. Microcontrollers can be programmed to execute pre-programmed instructions. The Arduino Nano is a microcontroller development board based on the ATmega328P chip with a very compact physical form. This Arduino lacks a DC power port and uses a mini USB type B connector for programming [14]. A relay is an electrically controlled switch and an electromechanical component that consists of two main parts: an electromagnet (coil) and a mechanical part (contactor or switch). Relays operate by utilizing the principle of electromagnetism to move the switch contacts, allowing low current (low power) to control a higher voltage [15]. LCD (Liquid Crystal Display) is a series of electronic devices that display information or indicators sent to a microcontroller. LCD screens have been implemented in various fields, including electronic devices such as televisions, computers, and even computer monitors. In the context of its application, the utilized LCD is a dot matrix type with the capacity to display 2 rows, and each row has 16 characters. The LCD screen serves as a display interface used to show the operational status of the instrument [16].

The cerebellar model articulation controller (CMAC) is one of the intelligent controls because it is claimed that its principle imitates human thought patterns and can provide decisions with a fast response. The fast response is shown because CMAC does not use numerical calculations to analyze the control dynamics that occur but uses a look up table method by reading certain database memory [17]. Fuzzy logic was first introduced by Jan Lukasiewicz in 1930 and initially promoted by Lotfi Zadeh in 1965 through the journal "Fuzzy Set." Fuzzy logic consists of three main stages: fuzzification, inference, and defuzzification [18]. Fuzzy Logic used for method it is known for being able to accommodate non-binary data and is non-linear so Fuzzy logic suitable for use because it uses linguistic values Which No linear. Fuzzy logic is used because there are limits to sensor values, parameters will be created to add water or replace water based on the water conditions [19]. Fuzzy logic controllers are categorized under intelligent control, offering the capability to solve complex system problems when conventional controllers have no ability to do [20].

To maximize water quality in terms of physical parameters, it is necessary to condition the water quality in the pool by monitoring the physical parameters, namely temperature, pH, dissolved oxygen levels and turbidity so that it can be maintained properly. The requirement to fulfill the above requirements so that the water in the pond is maintained is therefore needed to design a tool that can control the condition of the pond water for fish farmers in real time where the fish farmers are located. The purpose of this experiment is to design and build a water quality control system in a glass eel fish aquarium, look for accuracy values from readings of water quality measurement tools and to implementing a water quality control system in an aquarium using the Fuzzy Logic method.

2. Material and method

2.1. Research flow

The flow of research is very important to know and make sure that it is carried out the process of collecting data and analyzing data according to the flow that is designed so that there is no deviation from the expected research objectives. Fig. 1 shows the research flow. Based on Fig. 1, the research stages will be carried out as follows:

1. The first stage is studying references from research journals, both national and international research journals which are used as references in this research.
2. The second stage is designing and building the aquarium that will be used in this research.
3. The third stage is designing the tool hardware. The design is divided into tool design, water pump drive system design, and placement of the components used.
4. The fourth stage is hardware testing including sensor testing, whether the sensor can be read properly on the microcontroller and functions to control each factor and parameter that has been determined. If an error occurs it will return to stage 3.
5. The fifth stage is designing Fuzzy logic. Fuzzy logic design determines the input and output of a system. pH, temperature, and TDS as input and the length of time the pump and heater work are the output of this research.
6. The sixth stage is the application and testing of the Fuzzy logic method in the control system. The length of time the pump and heater are programmed with Fuzzy logic, the control system has been installed properly.
7. The seventh stage is data collection which is carried out to analyse the parameters that have been determined and the performance of the control system that is applied to the tool that has been made.
8. The eightd stage is writing a report on the results of the analysis of the research that has been carried out.

2.2. Fuzzy Logic

The reading values of the three sensors are used as input parameters in the Fuzzy inference system. The Fuzzy system processes three input parameters (pH, temperature, and TDS) based on rules that are created to produce output. The output of this system is the length of time in the process of returning the water quality.

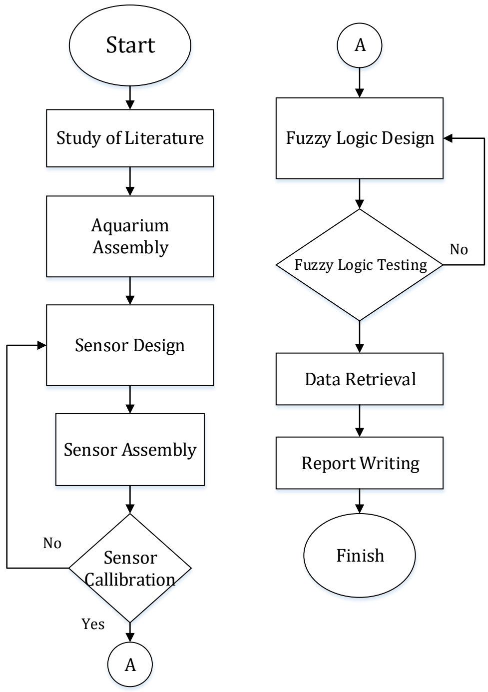

Figure 1. Research flow

Table 1.
Fuzzy sets

Variables	Fuzzy Sets	
	Linguistics	Numeric
pH Water	Low	5, 7
	Normal	6, 8
	High	7, 9
Temperature Water	Cold	25, 28
	Normal	25, 35
	Hot	32, 35
TDS Water	Normal	0, 600
	Not Normal	400, 1000
Pump Time	Off	0, 180
	Slow	180, 360
	Fast	360, 540
Heater Time	Off	0, 120
	On	120, 240

2.2.1. Fuzzification

The water quality control system consists of three inputs and one output which are fuzzified into Fuzzy sets. Fuzzy variables used as inputs are pH, temperature, and TDS and Fuzzy variables used as outputs are the length of time in the process of turning the water quality condition back to normal. Table 1 show the fuzzification tables.

2.2.2. Fuzzy rules

After forming fuzzification, Fuzzy rules are formed to make decisions in the form of Fuzzy output variables. Fuzzy output sets with membership functions determined based on the Mamdani method. This research uses 36 Fuzzy rules which can be seen as follows:

1. *If* (pH *is* High) *and* (Temperature *is* Cold) *and* (TDS *is* Normal) *then* (Heater *is* On) (1)
2. *If* (pH *is* Normal) *and* (Temperature *is* Cold) *and* (TDS *is* Normal) *then* (Heater *is* On) (1)

3. *If* (pH *is* Low) *and* (Temperature *is* Cold) *and* (TDS *is* Normal) *then* (Heater *is* On) (1)
4. *If* (pH *is* High) *and* (Temperature *is* Cold) *and* (TDS *is* Not_Normal) *then* (Heater *is* On) (1)
5. *If* (pH *is* Normal) *and* (Temperature *is* Cold) *and* (TDS *is* Not_Normal) *then* (Heater *is* On) (1)
6. *If* (pH *is* Low) *and* (Temperature *is* Cold) *and* (TDS *is* Not_Normal) *then* (Heater *is* On) (1)
7. *If* (pH *is* Low) *and* (Temperature *is* Normal) *and* (TDS *is* Normal) *then* (Heater *is* Off) (1)
8. *If* (pH *is* Low) *and* (Temperature *is* Hot) *and* (TDS *is* Normal) *then* (Heater *is* Off) (1)
9. *If* (pH *is* Normal) *and* (Temperature *is* Normal) *and* (TDS *is* Normal) *then* (Heater *is* Off) (1)
10. *If* (pH *is* Normal) *and* (Temperature *is* Hot) *and* (TDS *is* Normal) *then* (Heater *is* Off) (1)
11. *If* (pH *is* High) *and* (Temperature *is* Normal) *and* (TDS *is* Normal) *then* (Heater *is* Off) (1)
12. *If* (pH *is* High) *and* (Temperature *is* Hot) *and* (TDS *is* Normal) *then* (Heater *is* Off) (1)
13. *If* (pH *is* Low) *and* (Temperature *is* Normal) *and* (TDS *is* Not_Normal) *then* (Heater *is* Off) (1)
14. *If* (pH *is* Low) *and* (Temperature *is* Hot) *and* (TDS *is* Not_Normal) *then* (Heater *is* Off) (1)
15. *If* (pH *is* Normal) *and* (Temperature *is* Normal) *and* (TDS *is* Not_Normal) *then* (Heater *is* Off) (1)
16. *If* (pH *is* Normal) *and* (Temperature *is* Hot) *and* (TDS *is* Not_Normal) *then* (Heater *is* Off) (1)
17. *If* (pH *is* High) *and* (Temperature *is* Normal) *and* (TDS *is* Not_Normal) *then* (Heater *is* Off) (1)
18. *If* (pH *is* High) *and* (Temperature *is* Hot) *and* (TDS *is* Not_Normal) *then* (Heater *is* Off) (1)
19. *If* (pH *is* Normal) *and* (Temperature *is* Normal) *and* (TDS *is* Normal) *then* (Pump *is* Off) (1)
20. *If* (pH *is* Normal) *and* (Temperature *is* Cold) *and* (TDS *is* Normal) *then* (Pump *is* Off) (1)
21. *If* (pH *is* Normal) *and* (Temperature *is* Hot) *and* (TDS *is* Normal) *then* (Pump *is* Fast) (1)
22. *If* (pH *is* Low) *and* (Temperature *is* Cold) *and* (TDS *is* Normal) *then* (Pump *is* Fast) (1)
23. *If* (pH *is* Low) *and* (Temperature *is* Normal) *and* (TDS *is* Normal) *then* (Pump *is* Fast) (1)
24. *If* (pH *is* High) *and* (Temperature *is* Cold) *and* (TDS *is* Normal) *then* (Pump *is* Fast) (1)
25. *If* (pH *is* Normal) *and* (Temperature *is* Cold) *and* (TDS *is* Normal) *then* (Pump *is* Fast) (1)
26. *If* (pH *is* Normal) *and* (Temperature *is* Cold) *and* (TDS *is* Not_Normal) *then* (Pump *is* Fast) (1)
27. *If* (pH *is* Normal) *and* (Temperature *is* Normal) *and* (TDS *is* Not_Normal) *then* (Pump *is* Fast) (1)
28. *If* (pH *is* High) *and* (Temperature *is* Hot) *and* (TDS *is* Normal) *then* (Pump *is* Slow) (1)
29. *If* (pH *is* Low) *and* (Temperature *is* Hot) *and* (TDS *is* Normal) *then* (Pump *is* Slow) (1)
30. *If* (pH *is* Low) *and* (Temperature *is* Cold) *and* (TDS *is* Not_Normal) *then* (Pump *is* Slow) (1)
31. *If* (pH *is* Low) *and* (Temperature *is* Normal) *and* (TDS *is* Not_Normal) *then* (Pump *is* Slow) (1)
32. *If* (pH *is* Low) *and* (Temperature *is* Hot) *and* (TDS *is* Not_Normal) *then* (Pump *is* Slow) (1)
33. *If* (pH *is* Normal) *and* (Temperature *is* Hot) *and* (TDS *is* Not_Normal) *then* (Pump *is* Slow) (1)
34. *If* (pH *is* High) *and* (Temperature *is* Cold) *and* (TDS *is* Not_Normal) *then* (Pump *is* Slow) (1)
35. *If* (pH *is* High) *and* (Temperature *is* Normal) *and* (TDS *is* Not_Normal) *then* (Pump *is* Slow) (1)
36. *If* pH *is* High) *and* (Temperature *is* Hot) *and* (TDS *is* Not_Normal) *then* (Pump *is* Slow) (1)

2.2.3. *Deffuzification*

The input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the resulting output is a number in the fuzzy set domain. The defuzzification method used in this study is the COA (Center of Area) method. The solution for this method is that crisp is obtained by taking the center point of the Fuzzy region.

3. Results and discussions

The data that has been collected is processed using several types of data testing which are taken with several types of sensors, such as pH sensors, temperature sensors, and TDS sensors.

3.1. *pH system testing*

The initial step in this research involves the calibration testing of the pH sensor, comparing it with a pH meter, which is a measuring tool used to determine pH values typically employed for measuring water pH. Calibration is conducted using pH buffer dissolved in 50 ml of water stored in a measuring glass. The pH buffer used has a value of 4.01 pH.

Table 2.
pH sensor calibration results

Time (min)	(pH)			Accuracy (%)
	pH Meter	Sensor	Differences	
1	4,0	4,05	0,05	98,75
2	4,0	4,06	0,06	98,5
3	4,0	4,06	0,06	98,5
4	4,0	4,04	0,04	99,0
5	4,0	4,04	0,04	99,0
Average Value			0,05	98,75

Group Statistics

	pH	N	Mean	Std. Deviation	Std. Error Mean
Calibration Result	pH Meter	5	4.0000	.00000	.00000
	pH Sensor	5	4.0500	.01000	.00447

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Calibration Result	Equal variances assumed	16.000	.004	-11.180	8	.000	-.05000	.00447	-.06031	-.03969
	Equal variances not assumed			-11.180	4.000	.000	-.05000	.00447	-.06242	-.03758

Figure 2. pH T-Test Result

From the data in Table 2, the calibration results between the pH sensor and pH meter using a pH buffer solution of 4.01 dissolved in 50 ml of water show a difference of 0.05 and an accuracy level of 98.75%. In this research, before proceeding to the data collection stage, a T-Test was conducted first. Here are the results of the T-Test that have been carried out.

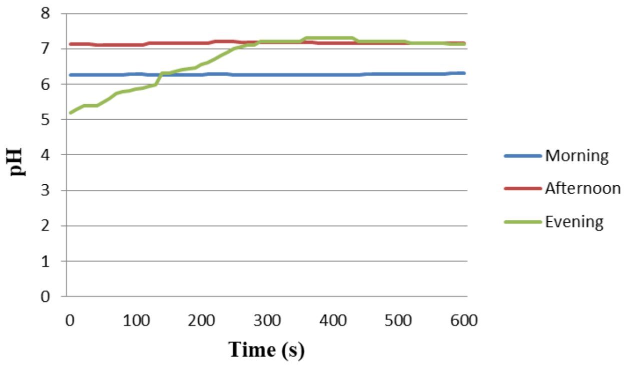

Figure 3. pH control graph

Table 4.
Temperature sensor calibration results

Time (Min)	Termometer (°C)	Themistor (°C)	Differences (°C)	Accuracy (%)
1	49	49,7	0,7	98,59
2	49	49,5	0,5	98,98
3	49	49,1	0,1	99,79
4	48	48,8	0,8	98,36
5	48	48,1	0,1	99,79
Average Value			0,4	99,10

Group Statistics

	Temperature	N	Mean	Std. Deviation	Std. Error Mean
Calibration Result	Thermometer	5	48.6000	.54772	.24495
	Thermistor	5	49.0400	.63087	.28213

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Calibration Result	Equal variances assumed	.002	.962	-1.178	8	.273	-.44000	.37363	-1.30159	.42159
	Equal variances not assumed			-1.178	7.845	.273	-.44000	.37363	-1.30456	.42456

Figure 4. Temperature T-Test Result

The output results from the "Independent Simple Test" within the "Equal Variances Assumed" section indicate a Sig. (2-tailed) value of 0.000, which is less than 0.05. According to the decision-making guidelines in the independent sample T-Test, a significant disparity in pH exists between the Sensor and pH Meter.

The pH system underwent testing during morning, afternoon, and evening sessions to regulate the aquarium's pH value to align with the desired setpoint. Setpoints utilized in aquariums typically span from pH 6 to pH 8. The output derived from Fuzzy logic in this study manifests as pump duration, regulating the water pump's initiation time to attain the targeted pH value.

Based on Fig. 3, the pH in the morning is lower than in the afternoon and at night, because during the day the air temperature is more extreme and causes the water temperature during the day to be higher and at night the air temperature is warmer than during the day. Testing in the morning the pH had increased from 6.25 to 6.29, during the afternoon the pH increased from 7.13 to 7.16. While at night the pH decreased from 5.2 to 7.1. At night the sensor reads that the pH at night does not match the setpoint in the aquarium. Inappropriate changes in pH value will be controlled by system so the pH value in the aquarium in accordance with set point. Based on the calculation results from Fuzzy logic, at night the pump runs for 270 seconds. The results of the pH value of the water after the pump is turned on are in accordance with the desired pH level.

3.2. *Temperature system testing*

The next step in this research involves testing the calibration of the temperature sensor by comparing it with a thermometer, which is a measuring instrument used to determine temperature values commonly employed for measuring water temperature. The temperature sensor used is a thermistor NTC 10k. The sensor testing is conducted using 100 ml of water stored in a measuring glass.

Based on Table 4, the calibration results for the temperature sensor and thermometer were obtained using 100 ml of water stored in a measuring glass, with the water being preheated. According to the testing results, calibration is not necessary, as the accuracy level obtained after a 5-minute test shows an accuracy value of 99.10%. In this research, before proceeding to the data collection stage, a T-Test was conducted first. Here are the results of the T-Test that have been carried out.

Based on the above output, the value of Sig. Levene's Test for Equality of Variances is 0.962 > 0.05. This indicates that the variance of data between the Thermometer and Thermistor is homogeneous or equal. Based on the output results of the "Independent Simple Test" in the "Equal variances assumed" section, it is noted that the Sig. (2-tailed) value is 0.273 > 0.05. Therefore, according to the decision-making basis in the independent sample T-Test, it can be concluded that there is no significant difference between the Thermometer and Thermistor.

Table 5.
Temperature control

	Morning	Afternoon	Evening
0	26,7°C	31,4°C	29,3°C
100	27,8°C	31,6°C	29,2°C
200	28,53°C	31,5°C	29,22°C
300	28,51°C	31,4°C	29,22°C
400	28,49°C	31,5°C	29,24°C
500	28,48°C	31,6°C	29,22°C
600	28,35°C	31,6°C	29,21°C

Temperature system testing is carried out in the morning, afternoon, and evening. This test is carried out to control the temperature on aquarium to match the desired setpoint. Setpoint used on aquarium range of 28°C to 32°C.

The control graph shown in Fig. 5 shows the results of temperature control test, in the morning the initial temperature value was 26.7°C to 28.35°C, during the day 31.4°C to 31.6°C and at night 24.6°C to 28.5°C. In the morning the sensor read that the temperature in the morning and at night did not match the setpoint in the aquarium. Improper changes in temperature value will be controlled by system so the temperature value in the aquarium in accordance with setpoint. Based on the calculation results from Fuzzy logic, in the morning the heater turns on for 124 seconds and at night the heater turns on for 180 seconds. The resulting water temperature value after the heater is turned on is in accordance with the desired temperature level.

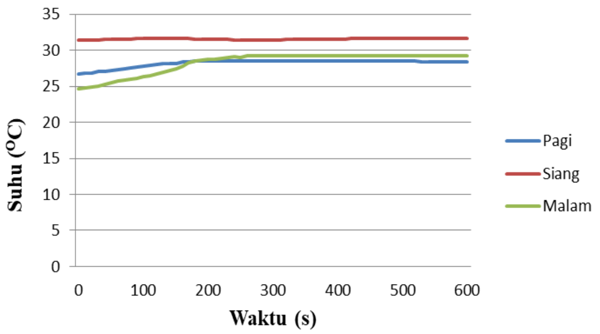

Figure 5. Temperature control graph

3.3. *TDS system testing*

The next step in this research involves calibrating the TDS sensor by comparing it with a TDS meter, which is a measuring tool used to determine TDS values commonly employed for measuring TDS in water. Sensor calibration is carried out using 50 ml of water stored in a measuring glass.

Based on Table 6, the calibration results between the TDS sensor and TDS meter using TDS buffer 1016 stored in a measuring glass of 50 ml show a difference of 5.6 ppm and an accuracy level of 99.44%. In this research, before proceeding to the data collection stage, a T-Test was conducted first. Here are the results of the T-Test that have been carried out.

Table 6.
TDS sensor calibration results

Time (Min)	TDS (ppm)			Accuracy (%)
	TDS	Sensor	Differences	
1	1016	1020	4	99,60
2	1016	1020	4	99,60
3	1016	1024	8	99,21
4	1016	1024	8	99,21
5	1016	1020	4	99,60
Average Value			5,6	99,44

Based on the output results of the "Independent Simple Test" in the "Equal variances assumed" section, it is known that the Sig. (2-tailed) value is 0.000 < 0.05. Therefore, following the decision-making basis in the independent sample T-Test, there is a significant difference in TDS between the TDS Sensor and TDS Meter.

TDS system testing is carried out in the morning, afternoon and evening. This test is carried out to control the TDS on aquarium to match the desired setpoint. Setpoint used on aquarium range from 0 ppm to 600 ppm.

The results of the TDS graph in Fig. 7 testing in the morning TDS with values ranging from 207.5 ppm to 207.9 ppm, during the day it increased with values ranging from 225.3 ppm to 227.4 ppm, while at night it showed TDS with values ranging from 205.9 ppm up to 209.7 ppm. Changes in TDS values that occur are due to the evaporation process in aquarium water in the morning, afternoon, and evening, which causes TDS to change according to the environmental temperature in the aquarium.

Group Statistics

	TDS	N	Mean	Std. Deviation	Std. Error Mean
Calibration Result	TDS Meter	5	1016.0000	.00000	.00000
	TDS Sensor	5	1021.6000	2.19089	.97980

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Calibration Result	Equal variances assumed	96.000	.000	-5.715	8	.000	-5.60000	.97980	-7.85941	-3.34059
	Equal variances not assumed			-5.715	4.000	.005	-5.60000	.97980	-8.32035	-2.87965

Figure 6. TDS T-Test result

Table 7.
TDS control table

	Morning	Afternoon	Night
0	207,5	225,3	214,2
100	208,2	226	214,4
200	207,7	227	214,8
300	206,9	227,5	214,6
400	205,9	227,3	214,2
500	207,3	227	214,3
600	207,9	227,4	214

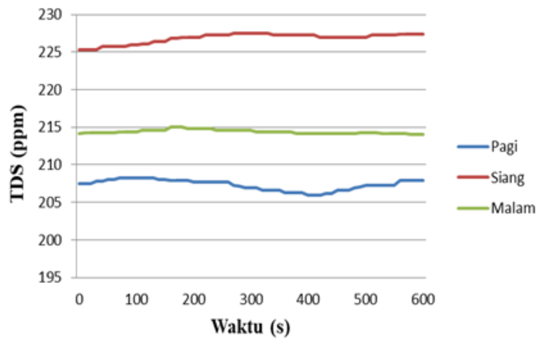

Figure 7. TDS control graph

4. Conclusions

Based on the results of the design and testing of the water quality control system with the parameters pH, temperature and TDS using Fuzzy logic that has been carried out in this study the following conclusions can be obtained, the results of the sensor readings can be seen that the water quality in the Workshop has water that is very suitable for use in aquariums , this is based on the results of the data obtained where the results of the pH sensor data show that the vulnerable pH value of the water is still in accordance with the setpoint value , which is worth 6.25 to 7.16, the TDS sensor shows a ppm value of 207 to 227 ppm and in measuring the temperature of aquarium water, at in the morning it hits a number below 28°C, based on the calculation results from Fuzzy logic in the morning the heater turns on for

124 seconds. From the results of water quality measurements, it is known that the tool can measure pH with an accuracy rate of 99.17%, temperature with an accuracy rate of 99.10%, and TDS with an accuracy rate of 99.44%. The system successfully works to control the aquarium using Fuzzy logic and successfully displays measurement data and all indicators on the aquarium control system for each measurement.

Declaration statement

Rocky Alfanz: **Conceptualization, Methodology, Writing-Original Draft**. Romi Wiryadinata, Fragrans Anjasmara Sobar, Imamul Mutakkin: **Collecting data.** Ipick Setiawan, Alif Maulana: **Writing-Review & Editing**

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article or its supplementary materials.

References

[1] Samsundari. S and G. A. Wirawan, "Analisis Penerapan Biofilter Dalam Sistem Resirkulasi Terhadap Mutu Kualitas Air Budidaya Ikan Sidat (Anguilla Bicolor)," *J. Gamma,* vol. 8, p. 2, 2013, [Online]. Available: http://ejournal.umm.ac.id/index.php/gamma/article /view/2410.

[2] Y. Sugianti, M. R. A. Putri, and S. E. Purnamaningtyas, "Spesies Ikan Sidat (Anguilla Spp.) dan Karakteristik Habitat Ruayanya di Sungai Cikaso, Sukabumi, Jawa Barat," *Limnotek Perair. darat Trop. di Indones.*, vol. 27, no. 1, pp. 39–54, 2020.

[3] Syahrul, N. Muhammad, Fajriani, Takril, and R. Fitriah, "Analisis Kesesuaian Kualitas Air Sungai Dalam Mendukung Kegiatan Budidaya Perikanan di Desa Batetangnga, Kecamatan Binuang, Provinsi Sulawesi Barat," *SIGANUS J. Fish. Mar. Sci.*, vol. 3, no. 1, pp. 171–181, 2021, doi: 10.31605/siganus.v3i1.1210.

[4] G. Imaduddin and A. Saprizal, "Otomatisasi Monitoring Dan Pengaturan Keasaman Larutan Dan Suhu Air Kolam Ikan Pada Pembenihan Ikan Lele," *J. Sist. Informasi, Teknol. Inform. dan Komput.*, vol. 7, no. 2, pp. 28–35, 2017, [Online]. Available: https://jurnal.umj.ac.id/index.php/just-it/article/view/1064.

[5] D. Azhari and A. M. Tomasoa, "Kajian Kualitas Air dan Pertumbuhan Ikan Nila (Oreochromis niloticus) yang Dibudidayakan dengan Sistem Akuaponik," *Akuatika Indones.*, vol. 3, no. 2, p. 84, 2018, doi: 10.24198/jaki.v3i2.23392.

[6] F. A. Sukoco, B. S. Rahardja, and A. Manan, "PENGARUH PEMBERIAN PROBIOTIK BERBEDA DALAM SISTEM AKUAPONIK TERHADAP FCR (FEED CONVERTION RATIO) DAN BIOMASSA IKAN LELE (Clarias sp.)," *J. Aquac. Fish Heal.*, vol. 6, no. 1, p. 24, 2019, doi: 10.20473/jafh.v6i1.11271.

[7] M. Faysal *et al.*, "Assessment of pH and total dissolved substances (TDS) in the commercially available bottled drinking water," *IOSR J. Nurs. Heal. Sci.*, vol. 6, no. 5, pp. 35–40, 2017, doi: 10.9790/1959-0605093540.

[8] S. Purwoto and W. Nugroho, "Removal Klorida, Tds Dan Besi Pada Air Payau Melalui Penukar Ion Dan Filtrasi Campuran Zeolit Aktif Dengan Karbon Aktif," *WAKTU J. Tek. UNIPA*, vol. 11, no. 1, pp. 47–59, 2013, doi: 10.36456/waktu.v11i1.861.

[9] A. F. Adella, M. F. P. Putra, F. Taufiqurrahman, and A. B. Kaswar, "Pintu Otomatis Berbasis Ultrasonic Internet of Things," *IoT*, vol. 17, no. 3, pp. 1–5, 2020.

[10] M. A. Askar, E. Susanto, and A. S. Wibowo, "Sistem Pengendalian Pakan Dan Monitoring Kualitas Air Akuarium Otomatis Automatic Aquarium Feed Control And Water Quality Monitoring System," *e-Proceeding Eng.*, vol. 9, no. 2, pp. 273–280, 2022.

[11] P. Y. P. Pratama, K. S. Wibawa, and M. A. D. Suarjaya, "Perancangan PH Meter Dengan Sensor PH Air Berbasis Arduino," vol. 3, no. 2, 2022.

[12] S. S. Munifah, Wiendartun, and A. Aminudin, "Design of temperature measuring instrument using NTC thermistor of Fe2TiO5 based on microcontroller ATmega 328," *J. Phys. Conf. Ser.*, vol. 1280, no. 2, 2019, doi: 10.1088/1742-6596/1280/2/022052.

[13] M. Martani and Endarko, "Perancangan Dan Pembuatan Sensor Level Untuk Sistem Kontrol Pada Proses Pengendapan CaCO3 Dalam Air Dengan Metode Medan Magnet," vol. 17, no. 3, pp. 99–108, 2014.

[14] M. Suari, "Pemanfatan Arduino nano dalam Perancangan Media Pembelajaran Fisika," *Nat. Sci. J.*, vol. 3, no. 1, pp. 474–480, 2017, [Online]. Available: www.ecadio.com.

[15] M. Saleh and M. Haryanti, "RANCANG BANGUN SISTEM KEAMANAN RUMAH MENGGUNAKAN RELAY," *J. Teknol. Elektro, Univ. Buana*, vol. 8, no. 2, pp. 87–94, 2017, [Online]. Available: https://media.neliti.com/media/publications/141935-ID-perancangan-simulasi-sistem-pemantauan-p.pdf.

[16] H. Suryantoro, "Prototype Sistem Monitoring Level Air Berbasis Labview dan Arduino Sebagai Sarana Pendukung Praktikum Instrumentasi Sistem Kendali," *Indones. J. Lab.*, vol. 1, no. 3, p. 20, 2019, doi: 10.22146/ijl.v1i3.48718.

[17] R. Maerani and S. Bakhri, "Perbandingan Sistem Pengontrolan PID Konvensional Dengan Pengontrolan Cmac, Fuzzy Logic Dan Ann Pada Water Level

Pressurizer," *Sigma Epsil.*, vol. 17, no. 3, pp. 129–141, 2013.

[18] A. K. Nisa, M. Abdy, and A. Zaki, "Penerapan Fuzzy Logic untuk Menentukan Minuman Susu Kemasan Terbaik dalam Pengoptimalan Gizi," *J. Math. Comput. Stat.*, vol. 3, no. 1, p. 51, 2020, doi: 10.35580/jmathcos.v3i1.19902.

[19] A. J. Kuswinta, I. G. P. W. Wedashwara W, and I. W. A. A. Arimbawa, "Implementasi IoT Cerdas Berbasis Inference Fuzzy Tsukamoto pada Pemantauan Kadar pH dan Ketinggian Air dalam Akuaponik," *J. Comput. Sci. Informatics Eng.*, vol. 3, no. 1, pp. 65–74, 2019, doi: 10.29303/jcosine.v3i1.245.

[20] A. Alimuddin, R. Arafiyah, I. Saraswati, R. Alfanz, P. Hasudungan, and T. Taufik, "Development and performance study of temperature and humidity regulator in baby incubator using fuzzy-pid hybrid controller," *Energies*, vol. 14, no. 20, 2021, doi: 10.3390/en14206505.