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Design of Filterization Monitoring System in Household Wastewater Treatment using IoT Based PID Method

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A B S T R A C T

This research aims to design and optimize the PID control system for FPV drones using Betaflight software. The main focus of this study is on tuning and adjusting PID parameters to achieve stability, responsiveness and optimal performance of the drone during extreme flight maneuvers. By utilizing Betaflight as the PID tuning platform, this research attempts to fine-tune the optimal values of proportional (P), integral (I), and derivative (D) to obtain precise and agile control responses. Through the optimization of the PID control system, it is expected that FPV drones can achieve high reliability and performance in tackling various flight challenges. The results of this research are expected to contribute to the development of advanced and effective FPV drones in executing complex flight maneuvers.

INTRODUCTION

The Problem of Domestic Wastewater Treatment, Household wastewater contains substances that can pollute the environment if not treated properly before disposal. The filtering process is used to remove contaminants and improve the quality of wastewater before being discharged into the environment. Needs Monitoring, The filtering process must be continuously monitored to ensure the efficiency of wastewater treatment. Manual monitoring can be time-consuming and ineffective in detecting changing conditions quickly.

IoT-Based Monitoring System, Internet of Things (IoT) is a technology that allows devices connected to the internet to communicate with each other and share data. Using IoT in filter monitoring systems allows real-time data transmission, remote monitoring, and data access via mobile devices or computers, PID Method in Control Systems, PID Method is a control method that can maintain the stability of control variables (for example, turbidity of wastewater) by calculating the control output based on the error (difference between the set point and the control variable). Using the PID method allows the system to automatically adjust control parameters to achieve the desired performance. Advantages of the Combination of PID and IoT Methods, The combination of PID and IoT methods enables monitoring and control that is more accurate and responsive to changing conditions. Data collected via sensors can be sent to the cloud or IoT platform for further analysis, visualization and remote monitoring. With internet connectivity, users can receive notifications and intervene if there is a problem with the filtering system.

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Domestic wastewater treatment is an important process to maintain environmental quality and human health. One of the important stages in wastewater treatment is filtration, in which wastewater is pumped through a filter medium to remove particles and contaminants. The PID (Proportional-Integral-Derivative) method is a control technique used to regulate a system by measuring the difference between the desired value and the actual value of the control variable, and calculating corrective actions to reduce the difference. This method can improve the accuracy and stability of the control system.

In wastewater treatment, a filtration monitoring system with the PID method can help improve filter efficiency and performance, by automatically adjusting the water flow and filter pressure based on the wastewater conditions measured by the sensor. In domestic wastewater treatment, IoT-based filtration monitoring systems can also provide additional benefits, such as remote monitoring and notifications to reduce response time in case of system problems. Therefore, the background of the filtration monitoring system in household wastewater treatment using the IoT-based PID method is very important to increase the efficiency and performance of wastewater treatment.

LITERATURE REVIEW

Previous Research

1. Research conducted by Ervina Junaidi and Achmad Choiruddin in 2018 with the title Household Wastewater Treatment Using Active Sand Filtration and Early Stage Aerobic Bacterial Activity in Lamtoro Gung Village, Samarinda Ilir District, Samarinda City. This study discusses domestic wastewater treatment with active sand filtration technology and aerobic bacterial activity.
2. Research conducted by Dianita Hidayati, Anisa Nur Istiqomah and Evi Mentari in 2020 entitled Domestic Wastewater Treatment Using Coconut Coir Media on a Lab Scale. This research discusses domestic wastewater treatment with coir media.
3. Research conducted by Fithriya Nur Asyiah, Sri Widyastuti and Istiarini in 2021 entitled “The Effectiveness of Domestic Wastewater Treatment Systems Using Sand Filters and Chlorine in Gadungan Hamlet, Karangsari Village, Bantul District, Bantul Regency”.This research discusses domestic wastewater treatment with sand and chlorine filters.Heading Level Ketiga

pH Sensor

A pH sensor is a device used to measure the concentration of hydrogen in a solution. Water and soil pH sensors need to be calibrated regularly to ensure accuracy.

Turbidity Sensor

Turbidity sensors are used to detect water quality by measuring the degree of turbidity. It uses light to detect suspended solids in water by measuring light transmission and light scattering rates, which change according to the amount of TTS (Total Suspended Solids).

Arduino Uno R3

Arduino is a microcontroller equipped with memory and input-output resources, and is made in the form of a prototyping board.

Actuators

Actuators is a mechanical device to drive or control a mechanism or system. Actuators are elements that convert analog electrical quantities into other quantities such as rotation speed and are electromagnetic devices that generate motion power so that they can produce motion in robots.

IoT Board

An IoT board is an electronic board designed to facilitate the development of Internet of Things (IoT) devices. IoT boards usually consist of a microcontroller, WiFi or Bluetooth module, user interface, and input/output (I/O) connections for sensors and actuators.

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Wi-Fi Module

A WI-FI module is a piece of hardware designed to allow electronic devices to connect to a WiFi network. A WiFi module usually consists of a WiFi chip and several supporting components, such as antennas and components to handle signaling and network connections.

Power Supply

A power supply is a device used to provide electrical power to electronic devices. Power supply can change the voltage and electric current from the received power source (for example AC electricity from the power grid or from DC batteries) to the value needed by the connected electronic device.

PID

PID (Proportional Integral Derivative controller) is a controller to determine the precision of an instrumentation system with the characteristics of feedback on the system. PID controllers are conventional controllers that are widely used in the industrial world.

METHODOLOGY

Research methods that can be used to design filter monitoring systems in household wastewater treatment using the IoT-based PID method may include the following steps: Literature study: Conduct a literature study to understand the basic concepts of wastewater filtration, household wastewater treatment, the PID method , and related IoT technologies. System design: Make an overall system design, which includes components such as sensors to detect wastewater quality, actuators to control filtering, microcontrollers or embedded systems as the brain of the system, communication with the IoT network, and user interfaces.

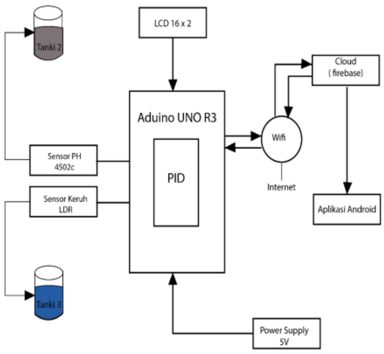
Data collection: Collect data on household wastewater quality that is relevant to the monitoring system. This data can include parameters such as turbidity, pH, content of certain chemicals, and others. Development of the PID algorithm: Design a suitable PID (Proportional-Integral-Derivative) algorithm to control the filtering system based on the wastewater quality data obtained. This algorithm will take into account the desired setpoint, sensor input, and produce the appropriate output for the actuator. Hardware and software implementation: Implement hardware such as sensors and actuators, as well as software that supports monitoring and control system functions using the PID algorithm.

System test: Perform a thorough system test to make sure the system is working properly. Tests can be carried out using quality controlled artificial wastewater or using actual household wastewater samples. Evaluation and analysis: Evaluation of monitoring and filtering system performance using the IoT-based PID method. Analysis of the resulting data to understand the effectiveness of the system in improving wastewater quality.

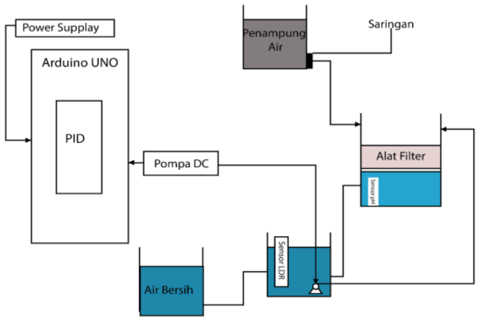
Discussion and conclusions: Discuss the research results and conclusions obtained from the implementation of the system. Also discuss the possibility of developing and upgrading the system in the future. At each of the steps above, it is important to pay attention to safety standards and applicable regulations regarding domestic wastewater treatment. Besides that,

System evaluation After system testing, the final step is to evaluate the system. System evaluation is carried out to see whether the system has achieved the expected goals and can be used effectively and efficiently for domestic wastewater treatment. While conducting this research, safety and environmental issues must also be considered when using a filtration control system in domestic wastewater treatment using the IoT-based PID method.

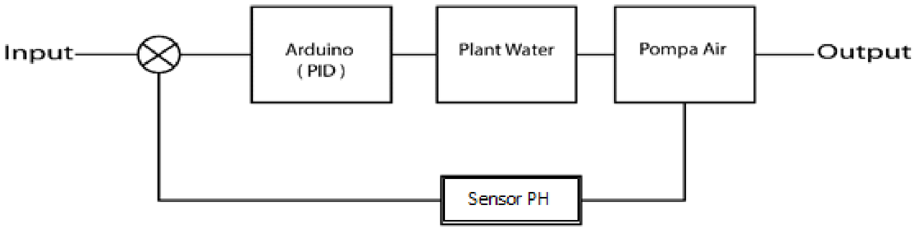
Block Diagrams



Pictures 1. Common Process Block Diagram



Pictures 2. Filterization Process Block Diagram



Pictures 3. Control System Diagram

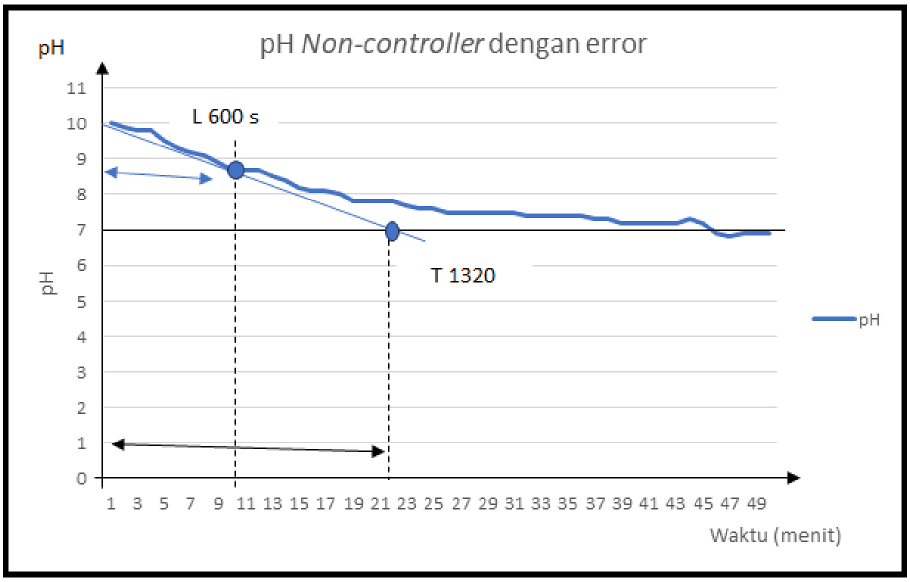


Figure 4. PID chart

L = 600 s

T = 1320 s

Kp = ½ x T:L

= ½ x 1320:600

=2,2

Ti = 2 x L

= 2 x 600

= 1200

To find value Ki

Ti = KP / Ki

1200 = 2,2 : Ki

1200 x Ki = 2,2

Ki = 2,2 : 1200

Ki = 0,001

Td = 0,5.L

Td = 0,5 x 600

Td = 300

To find value Kd

Td = Kd / Kp

300 = Kd / 2,2

Kd = 300 x 2,2

Kd = 660

RESULT AND DISCUSSION

Testing at this writing is divided into several stages, the initial stage is sensor testing, the next is IoT connection testing, and the last is testing the entire system

Testing the pH Sensor

Testing this sensor using a pH-4502c sensor as shown below

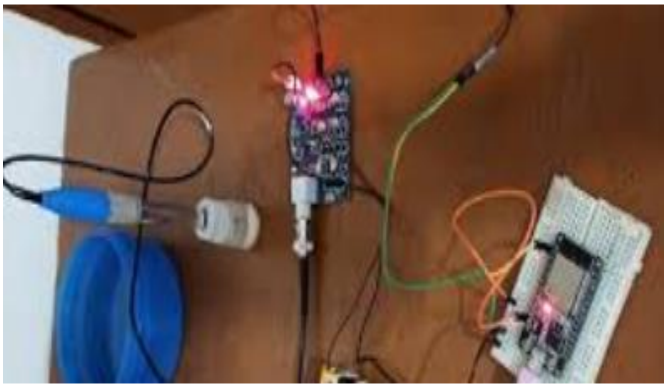


Figure 5. pH-4502c Sensor

In this test, the first thing to do is calibrate the pH sensor, calibration is done by entering the Arduino code. Calibration is a verification process that the accuracy of a measuring instrument is in accordance with its design. Calibration is usually done by comparing a standard that is linked to national and international standards and certified reference materials. The purpose of calibration is to achieve measurement traceability.

```
adcPH = analogRead(A0); //menggunakan pin A0 untuk membaca output sensor pH
voltage = adcPH *5.0/1022;
pHValue = (6.4516*voltage)-5.7742;
```

Figure 6. Calibration Coding

In Figure 6 it can be observed that the input pin used is analog input A0, after initialization, the reading value is converted using the adc formula to the variable named "voltage", and the variable "pHValue" is the variable used to store the calibrated pH value.

Table 1. Calibration Result Table

No	Calibrated Fluids	pH Meter	pH Sensor	Differents
1	Lime Juice	3.6	3.8	0.2
2	Sour Liquid	4.5	4.1	0.4
3	Dishwashing Water	5.3	5.9	0,5
4	Flour Clean Water	6.4	5.8	0,6
5	Tea Water	4.8	4.9	0.1
6	Faucet Water	6.6	6.4	0.2
7	Soap Water	8.9	8,6	0.3
8	Wet Liquid	9.5	8.9	0.4
			Avarange	0.3

Then calibration for this sensor is carried out with 8 liquids such as household tap water, lime juice, tea water, soapy water, dishwashing water, sukabirus kostan water, floor cleaning water, pH 4.10 buffer liquid, pH 6.86 buffer, buffer 9.18, the liquid raises the pH, namely 10% KOH, and the liquid lowers the pH, namely 10% $H3PO4$. The average value for pH calibration accuracy for each experiment was 0.9820. The calibration process refers to the following steps:

1. The pH sensor is placed in an ordinary water solution with a pH ranging from 7 which aims to be a reference point for sensor readings
2. The pH sensor is then placed in an acidic solution, namely lime juice and gets a pH reading of around 3.6.
3. The pH sensor is placed again in the plain water solution, to neutralize the reading.
4. The last step is the pH sensor is placed in an alkaline solution with a pH reading of 8.9.
5. Steps 2 and 3 aim to determine the upper and lower limits of the reading of the pH sensor according to this study.

Placing the sensor against the container does not sink completely, the sensor is immersed in the solution from the tip of the sensor is 4cm to the middle drat limit of the sensor. The volume used in this calibration process is 100 ml of solution placed in the same container.

Figure 7. Calibration data collection process

The picture above shows the process of collecting calibration data using several fluids.

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Table 2 The sensor test result area error

No	Time	The average value of the pH sensor is from 0 to 90 seconds	pH meter	Difference
1	0 second	6.9	6.6	0,3
2	10 second	7.2	6.5	0,7
3	20 second	6.8	6.5	0,3
4	30 second	6.8	6.4	0,4
5	40 second	6.7	6.3	0,4
6	50 second	7.1	6.6	0,5
7	60 second	6.9	6.5	0,4
8	70 second	6.8	6.5	0,3
9	80 second	7.2	6.6	0,3
10	90 second	7.2	6.6	0,6

In the data above, it can be seen that an error has occurred. The pH value may not be read correctly by the sensor or there is interference with the pH sensor device itself. It is important to record such occurrences in experiments and repeat measurements to obtain accurate and reliable data.

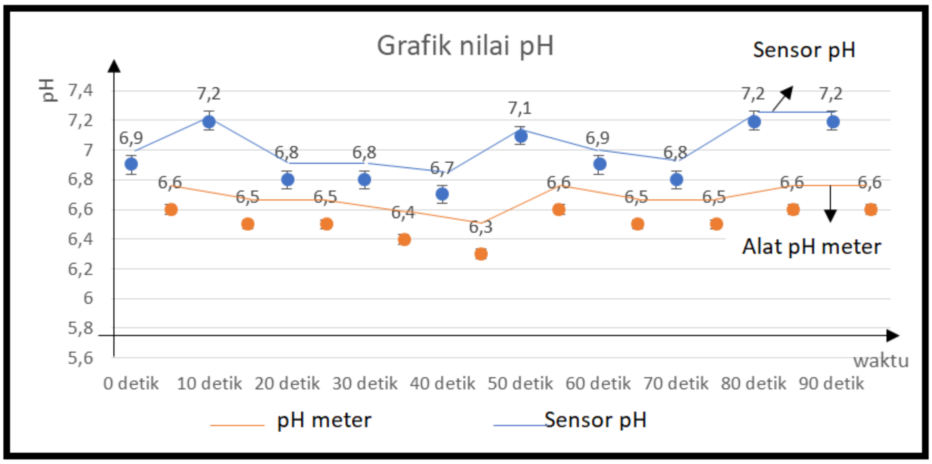

Figure 9. Graph of a pH value error

In Figure 9 above is a graph of the error pH value.

Network Testing for IoT

On network testing for IoT aims to test whether the connection can be connected to the network. In Figure 10 below, the Arduino serial monitor shows that the system can be connected as a server.

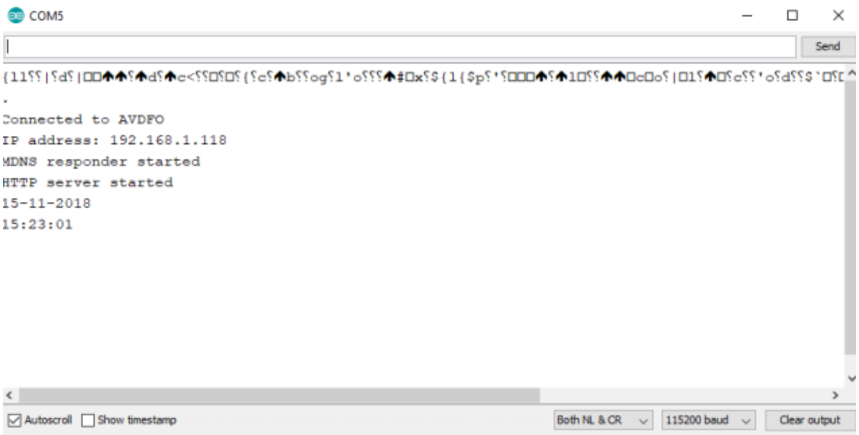

Figure 10. System Indicator

On Figure 10 can be observed that the system will enter the network with the WiFi name AVDPO, so that it can be accessed, the client must access via IP 192.168.1.118.

Testing with Filtration Systems

Below is the process of purifying or filtering water ph and water turbidity which is done 3 times per liter.

Table 3. Result of pH sensor controller

Volume	pH before filtering	pH level after filtering	Time
3 liters	6,3	7,2	15 minutes
	6,3	7,3	15 minutes
2 liters	6,3	7,2	13 minutes
	6,3	7,3	13 minutes
	6,3	6,8	11 minutes
	6,3	7,4	10 minutes
1 liters	6,3	7,1	8 minutes
	6,3	6,9	8 minutes
	6,3	6,8	7 minutes

From testing the pH level above, that the pH level of alkaline water processed in the water ionizer is greatly influenced by the processing time of the water in the water ionizer, and is also greatly influenced by the amount of volume of water that enters the water ionizer itself, if the volume is small, the faster also the time to process water into alkaline water, at 3 liters with an average time of 14 minutes, at 2 liters takes an average of 12 minutes and at 1 liter takes 8 minutes. Then the change in pH before filtering was 6.3 and the change in Ph after filtering was 7.2 on average.

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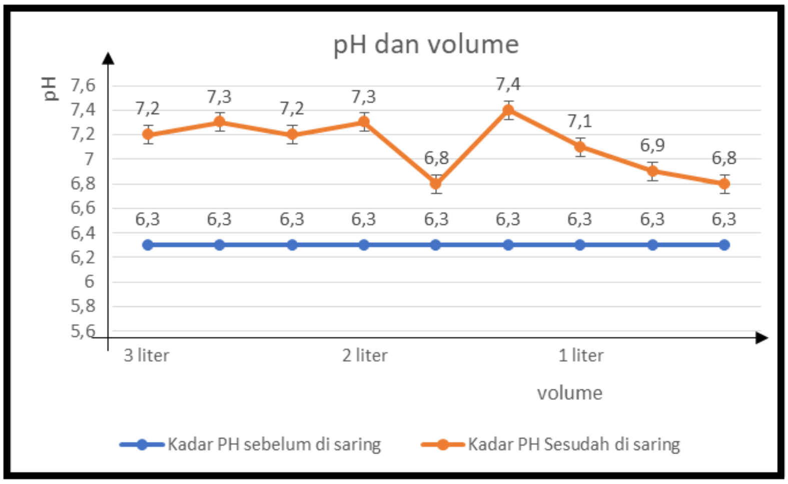

Figure 12. Volume pH

Figure 12 above shows an image of the pH and volume result

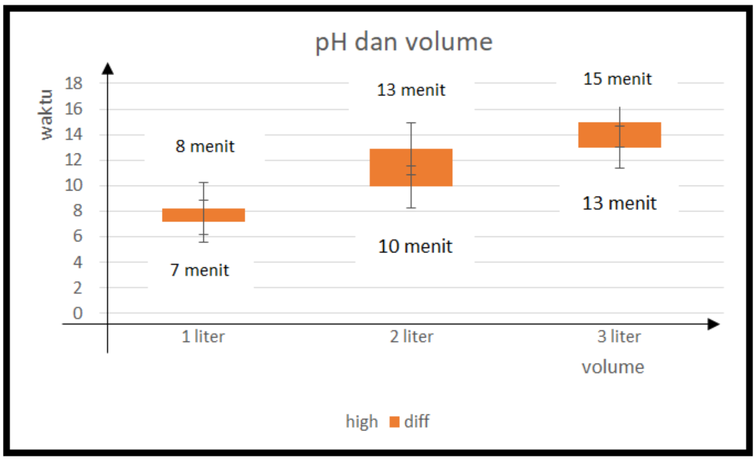

Figure 13. Volume and Time

In Figure 13 the chart above shows the results of the time and volume charts which show the highest and lowest times. The highest time for measuring 1 liter of water is 8 minutes and the lowest time is 7 minutes and for 2 liters the highest time is 13 minutes while the lowest time is 10 minutes and for 3 liters the highest time is 15 minutes and the lowest time is 13 minutes.

Table 4. Turbidity sensor controller results

Volume	Turbidity level before filtering	Turbidity level before filtering	Time
3 liters	3 NTU	0.4 NTU	10 menit
	3 NTU	0.5 NTU	10 menit
2 liters	3 NTU	0.5 NTU	10 menit
	3 NTU	0.3 NTU	10 menit
1 liters	3 NTU	0.7 NTU	10 menit
	3 NTU	0.4 NTU	10 menit
	3 NTU	0.6 NTU	10 menit
	3 NTU	0.9 NTU	10 menit
	3 NTU	0.3 NTU	10 menit
	3 NTU	0.5 NTU	10 enit

From the turbidity sensor test above, the turbidity level is also greatly influenced by the time the water settles in the container which is carried out after filtration is carried out.

NTU (Nephelometric Turbidity Unit) is a unit used in measuring the turbidity of water. The clarity of water can be measured using an instrument called a nephelometer, and the results are expressed in NTU units. The higher the NTU value, the higher the turbidity of the water.

Testing The Tool with The Second Trial Filterization System

Table 5. Testing the Tool with The Second Trial Filterization System

Volume	Turbidity level before filtering	Turbidity level before filtering	Time
3 liters	6,1	7,1	17 minutes
	6,1	7,1	17 minutes
2 liters	6,1	7,2	15 minutes
	6,1	7,1	13 minutes
	6,1	6,8	12 minutes
	6,1	7,2	12 minutes
1 liters	6,1	7,2	10 minutes
	6,1	6,9	9 minutes
	6,1	7.1	9 minutes

In the table above are the results of the filtering that was done with the tool that I made. On 3 liters with an average time of 16 minutes, on 2 liters takes an average of 12 minutes and on 1 liter takes 9 minutes. Then the change in pH before filtering was 6.3 and the change in Ph after filtering was 7.1 on average.

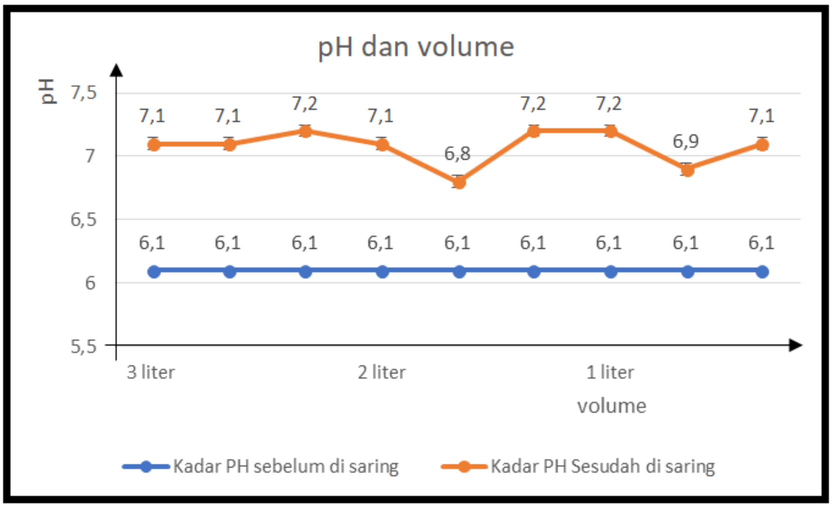

Figure 15. Graph of pH and Volume Filters Results

The picture above shows a graph of the pH level after and before being filtered and the time.

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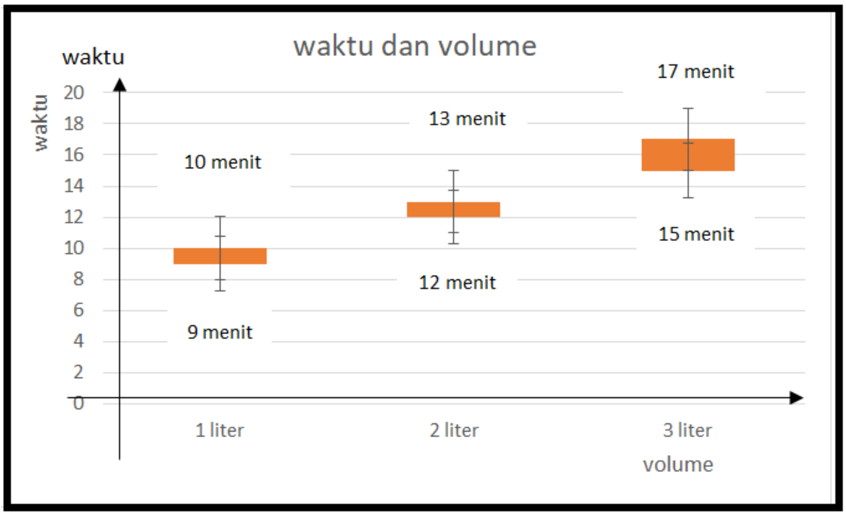

Figure 16. Volume and Time

The graphic image above shows the results of the time and volume charts which show the highest and lowest times. The highest time for measuring 1 liter of water is 10 minutes and the lowest time is 9 minutes and for 2 liters the highest time is 13 minutes while the lowest time is 12 minutes and for 3 liters the highest time is 17 minutes and the lowest time is 15 minutes.

Table 6. The results of turbidity measurements before and after filtering

Volume	Turbidity level before filtering	Turbidity level before being filtering	Time
3 liters	4 NTU	0.2 NTU	10 minutes
	4 NTU	0.5 NTU	10 minutes
2 liters	4 NTU	0.4 NTU	10 minutes
	4 NTU	0.3 NTU	10 minutes
1 liters	4 NTU	0.8 NTU	10 minutes
	4 NTU	0.4 NTU	10 minutes
	4 NTU	0.8 NTU	10 minutes
	4 NTU	0.7 NTU	10 minutes
	4 NTU	0.4 NTU	10 minutes
	4 NTU	0.8 NTU	10 minutes

Amplifier Module of the pH sensor

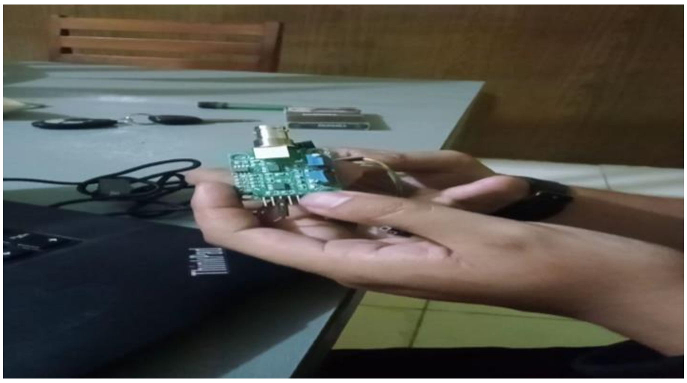

Figure 17. Amplifier Module

The table above shows the results of measuring the turbidity of water before and after being filtered. use the PO pin, V+ and G.

Tool Testing

Figure 18. Toll Testing

In Figure 18 above the experiment was carried out using used washing water filtered through a filter, namely the first ingredients are carbon, coir, small rocks and sand. Pada bagian ini berisi hasil dan pembahasan dari topik penelitian.

Filters Used

Figure 19. Filters Used

In Figure 19 this is the filter that is used in the waste water treatment tool that I made, this filter is useful for filtering dishwashing wastewater that will be processed.

L298N Module

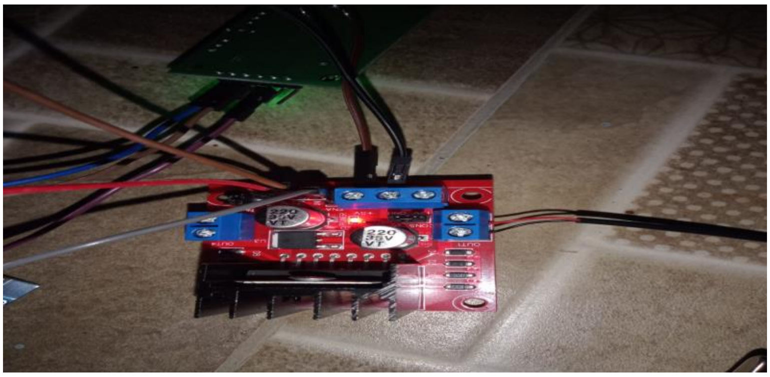

Figure 20. L298N Module

In Figure 19 above it is a module to control the PID pump.

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Retrieval of Pump Testing PID Data

Figure 21. PID Coding

The workings of the PID itself are to regulate the speed of the pump in regulating the acid liquid and wet liquid which will be added to the filtered water and if the pH level is still far from the set point 7 then the pump will automatically turn on and add acid liquid or wet liquid. Both the pump and sensor are controlled using Wemos.

Control signal = (kp x error) + (ki x error x time) + (kd x error x derivative x time)

Kp is a proportional constant

Ki is an integral constant

Kd is a derivative constant

The proportional component (P) in PID control provides a proportional response to the current error between the setpoint (desired value) and the controlled variable.

Integral component (I) in PID control provides a response to the accumulation of errors (integral of errors) over time. The derivative component (D) in the PID control responds to changes in the error rate.
Ziggler Nichole PID Method For Setting up the pump

Testing the Ziggler-Nichols PID method is an approach to determine the optimal PID control parameters for a specific system. The Ziggler-Nichols method has three main steps, namely:

1. First Step: Determine the Proportional Parameter (Kp), Set the integral (Ki) and derivative (Kd) parameters to zero. Increase the value of the proportional parameter (Kp) slowly until the system begins to oscillate. Record the Kp value while the system is agitated.
2. Second Step: Determine the Integral Parameter (Ki), Set the proportional parameter (Kp) to the value noted in the first step. Increase the integral parameter (Ki) value slowly until the system reaches the desired response within a reasonable amount of time. Record the Ki value when the system response is deemed adequate.
3. Third Step: Determine the Derivative Parameters (Kd), Set the proportional (Kp) and integral (Ki) parameters to the values noted in the previous step. Increase the value of the derivative parameter (Kd) slowly so that the system has a fast response and minimal distortion.

After following the steps above, you will get the appropriate Kp, Ki, and Kd parameters to set the water pump speed using the Ziggler-Nichols PID method. You can implement these parameters in a controller according to the water pump system used.

Table 7. PID Ziegler Nichols

	Kp	**Ti**	**Td**
P	T/L	∞	0
PI	0,9T/L	L/0,3	0
PID	1,2T/L	2L	0,5L

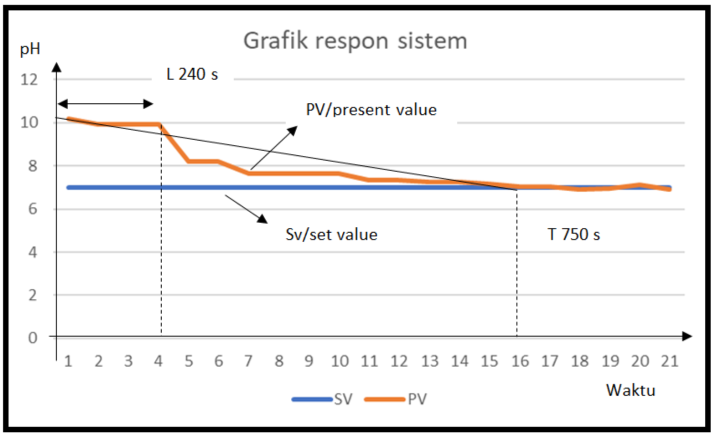

Figure 22. System Response Graph using PID

Table 8. The Results of The PID System Response Analysis Are Shown in The Graph Above.

No	**Response**	**Duration**	**Value (Start-End)**
1	*Setting time*	-	10-7
2	*Rise time*	-	10-9,56
3	*Peak time*	-	10
4	*Delay time*	-	0-10
5	*Overshoot*	-	0,42%

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The table above shows that the final value response - the initial setting time value is 10-7, Rise time 10-9.56, Peak time 10, Delay time 0-10, Overshoot 973 0.42%

Overall System Testing

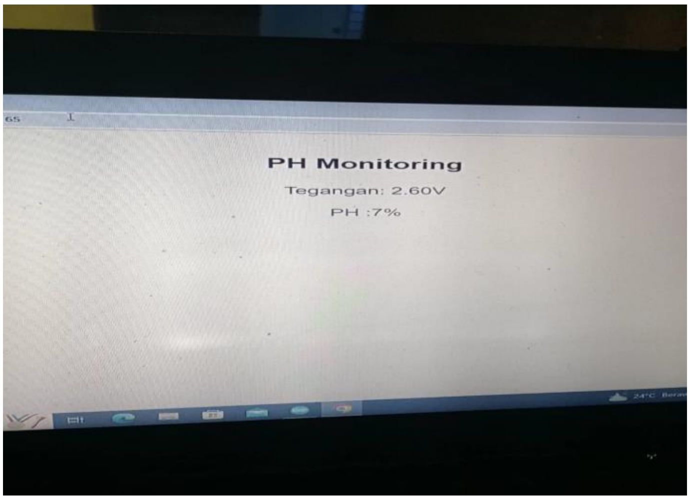

Figure 23. Client Display when Accessing Arduino

In this test, after all the blocks have been tested, the next step is to test the monitoring system with IoT, in Figure 23 is an illustration of the IoT system with Arduino connected to the network as a server, reading the filtered water pH sensor, and accessing it via laptops

CONCLUTION AND SUGGESTIONS

Conclution

Efficiency because the error value of the sensor is 6.5 and the effectiveness of the tool that I made after filtering can get a better ph value of 6.8 and the water is cleaner and suitable for use with the filtration results that are done this is very useful because it does not endanger the surrounding environment if disposed of. The results of testing the system obtained the PID KP value: 2.2 Ki: 0.001 and Kd: 660. The results of the system response graph using PID show that the final value response - the initial value of setting time duration 10-7, Rise time 10-9.56, Peak time 10, Delay time 0-10, Overshoot 973 0.42%. The use of IoT in the filter control system in household wastewater treatment can provide convenience in controlling and retrieving data in the form of water pH and water turbidity levels and can also be controlled remotely.

Suggestions

In this final project, the system has been designed to monitor and control the filtering of household wastewater. However, you can consider developing additional features and functions to improve the functionality of the system. In this final project, it is possible to have conducted several tests to test the system of the system. However, to increase the confidence and reliability of the system, it could continue with further testing and validation and could also perform different tests than this one. Development of the pH sensor if there is one in the future.

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