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DESIGN OF WATER QUALITY MEASURING INSTRUMENT BASED ON TURBIDITY, TOTAL DISSOLVED SOLIDS, AND pH VALUES

Yasmin Nabilah[1], Ma'murotun[1], and Atika Hendryani[1]
[1,2,3] Department of Electromedical Engineering, Health Polytechnic of Ministry of Health Jakarta 2, Indonesia
Corresponding author: Yasmin Nabilah (e-mail: p22030121055@poltekkesjkt2.ac.id).

ABSTRACT Drinking water is water that has been through a processing process or without a processing process that meets health requirements and can be directly drunk. Drinking water requirements in Indonesia are regulated in the regulation of the Minister of Health of the Republic of Indonesia in Permenkes RI Number 492/MENKES/PER/IV/2010. Three of several mandatory parameters to meet the requirements for drinking water quality are turbidity levels, total dissolved solids (TDS), and pH values. In addition, this tool can also be used to determine the quality of RO water in hemodialysis equipment and calculate its content values based on the three sensors used. The purpose of this study is to develop a water quality measuring tool consisting of three parameters but contained in one tool. This tool uses a turbidity sensor, a TDS sensor, and a pH sensor with a 20x4 LCD as a display of the test results. Sample testing uses 4 types of samples: distilled water, bottled drinking water, refilled depot water, and RO water from hospitals for hemodialysis equipment. The accuracy of pH sensor measurements with a pH 6.86 buffer solution was 97.38%, TDS sensor with a standard solution of 342 PPM was 79.65%, and turbidity sensor with a standard solution of 0 NTU was 100%. The results of the test have been able to classify water into categories that meet quality and do not meet quality.

INDEX TERMS Water, Turbidity Sensor, TDS Sensor, pH Sensor, Arduino Uno, TFT 20x4

I. INTRODUCTION

Water is one of the basic necessities for living things, especially for daily needs. The availability of clean water is crucial for maintaining health and well-being [1]. Biologically, the human body is composed of approximately 60% water, which functions in various vital processes, including digestion, circulation, body temperature regulation, and excretion [2].

Drinking water is water that has undergone a process or is unprocessed and meets health requirements and is suitable for direct consumption [3]. Humans need water for their daily needs. The need for clean water continues to increase year after year. However, the supply of clean water on earth is dwindling. Various factors can affect water quality, including turbidity and dissolved substances [4].

Based on the Regulation of the Minister of Health of the Republic of Indonesia number 75 of 2013 concerning the Recommended Nutritional Adequacy Intake (AKG) for the Indonesian people, namely 1,900 ml for children aged 7 to 9 years and 1,800 ml for children aged 10 to 12 years. Meanwhile, for adults, the recommended water consumption is around eight glasses of 2,300 ml per day or a total of 2 L [5].

Water turbidity is a condition in which water contains suspended particles that can be soil, mud, microorganisms, or organic materials [6]. These particles cause the water to appear cloudy or opaque.

The level of turbidity is an important indicator of drinking water quality, because high turbidity can indicate the presence of contaminants, either physical particles or microbes that are harmful to health [7].

When someone consumes drinking water with a high pH, it means the acid balance in the body will be maintained. A high pH in drinking water can make the blood pH more alkaline or basic, which is believed to be beneficial for the body [8]. If someone consumes drinking water with a low pH level, the body will experience acidosis, which will cause symptoms such as nausea [9]. Therefore, the acidity level of drinking water also needs to be considered to maintain body health. Furthermore, drinking water with a pH that is too acidic or too basic will have an unpleasant taste [10].

According to the Regulation of the Minister of Health of the Republic of Indonesia Number 492/MENKES/PER/IV/2010 concerning Drinking Water Requirements, drinking water is water whose quality must meet health requirements, both in terms of microbiology, chemistry, physics, and radioactivity which are included in the mandatory parameters and additional parameters. The recommended levels for drinking water in Total Dissolved Solids (TDS) are less than 500 mg/L, turbidity less than 5 NTU, and pH values with a range of 6.5-8.5 pH [11].

Research by Reforma et al. (2021) [12] conducted research on a turbidimeter device for measuring clean water quality using a turbidity sensor to read the turbidity level in the water and a TDS sensor to measure the amount of dissolved solids in the water. The results showed an error value for the TDS sensor of 2.11% and a turbidity sensor of 3.86%.

Research by Suliyani et al. (2022) [13] conducted research on a turbidimeter tool to measure clean water quality using a phototransistor and infrared sensor to read the turbidity level in water, Arduino Uno as a microcontroller, and I2C LCD to display the value. In the test, a sample of distilled water mixed with soil and ash impurities was used. The results of the study showed an average turbidity accuracy value for groundwater of 94.66% and ash water of 96.63%.

Research by Zanira (2024) [14] conducted research on drinking water quality measuring instruments using turbidity sensors to measure the level of turbidity in water and pH sensors to read the pH value in water, and can categorize it into meeting quality and not meeting quality. The results of testing pH values with pH solutions of 4.01, 6.86, and 9.18 showed an average error value of 8.12%. Testing turbidity values using 0 NTU and isotonic 100 NTU aquadest showed an average error value of 1.27%. The results of testing on test samples of 5 solutions in the form of bottled water, high pH bottled water, refill depot water, tap water, and boiled tap water showed an average error value of 4.15%.

Based on the background outlined above and based on various previous studies, the author desires to design a tool for detecting water quality based on turbidity, total dissolved solids, and pH. This research can detect the turbidity, total dissolved solids, and pH values of water samples being tested, and these values will be displayed on a display as an indicator of whether the water meets or fails the quality threshold. With this tool, the author hopes to provide a single tool for measuring water quality, including turbidity, total dissolved solids, and pH, for ease of use and laboratory testing.

II. RESEARCH METHODS AND SYSTEM DESIGN

This study proposes a system design by updating the existing system, namely a water quality measurement tool equipped with turbidity, total dissolved solids, and pH parameters in one tool. The overall stages of the research process from initial planning to analysis and conclusion.

A. BLOCK DIAGRAM

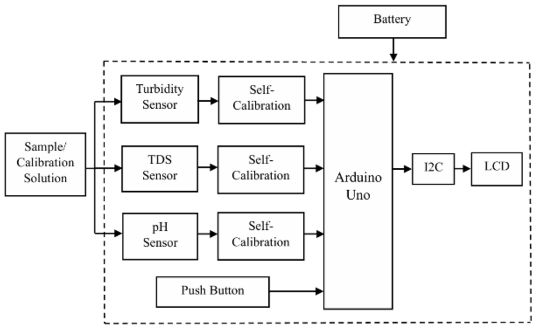

FIGURE 1. This block diagram describes the workflow of the tool to be created.

The block diagram in Fig. 1 illustrates how the main battery power source is used to supply voltage to the entire circuit. The Arduino Uno serves as the main controller for the module's overall operation. When the module is to be used, it must first be self-calibrated by selecting the self-calibration menu. After self-calibrating the three sensors, the module can be used by pressing the sample test button to start the measurement and immersing the sensor in the sample to be examined. The sensor will read the measurement results in the form of analog data which will then be processed by the Arduino Uno's internal ADC. The results of this measurement will be displayed on the LCD in NTU, PPM, and pH indicators, as well as whether or not a sample meets the quality for consumption as drinking water.

B. FLOWCHART

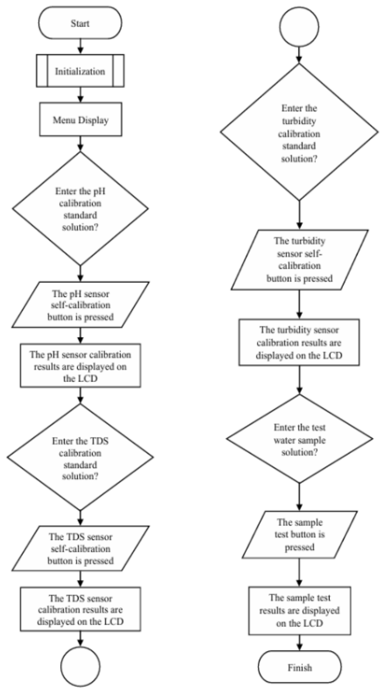

FIGURE 2. Flowchart design on a tool that describes the tool's workflow.

C. SCHEMATIC DESIGN

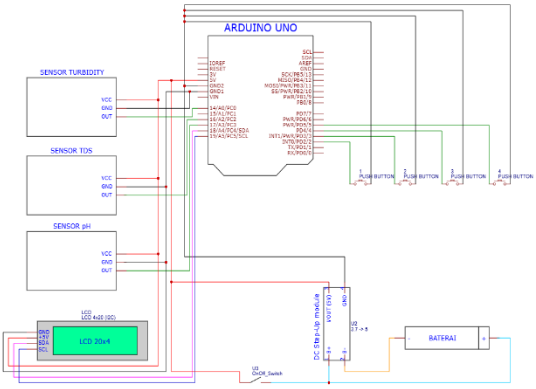

FIGURE 5. In the schematic circuit design, the tool consists of an arduino uno, turbidity sensor, TDS sensor, pH sensor, 20x4 I2C LCD, step-up charger module, push button, on/off switch, and battery.

The way this tool circuit works is when the on/off switch is pressed, the battery supply which is worth 3.7 V will be increased using a step up charger module to 5 V whose resulting voltage will be distributed to the Arduino Uno as the control center of the tool. Then the Arduino Uno will initialize all connected components, including the turbidity sensor, TDS sensor, pH sensor, and 20x4 LCD. After initialization is complete, the tool will wait for a command. If the push button for the pH sensor is pressed, the tool will measure the pH of the water. Likewise, if the push button for the TDS sensor is pressed, the tool will measure the TDS level in the water, and if the push button for the turbidity sensor is pressed, the tool will measure the turbidity level in the water.

After the push button is pressed, the sensor will output an analog signal, and the microcontroller will convert it using an ADC (analog to digital). This circuit uses an 8-bit Arduino Uno ATmega 328P microcontroller. This means the processor processes 8-bit data in one cycle. Although the Arduino Uno processor is 8-bit, its ADC (Analog-to-Digital Converter) module is 10-bit. This means the reading value from analogRead() will range from 0 to 23 (2^{10} = 1024 levels of resolution).

When the sample test button is pressed, the three sensors work simultaneously to measure the pH, TDS, and turbidity levels in the water. The Arduino then processes the analog data from the three sensors. The results are then displayed on a 20x4 LCD.

III. RESULT AND DISCUSSION

A. PHYSICAL FORM OF THE DEVICE

The developed device is designed with a compact and user-oriented hardware interface. As shown in Fig. 6 the front view, the device is equipped with a liquid crystal display (LCD) that functions as the primary output interface for presenting measurement and analysis results in real time. Beneath the display, four color-coded push buttons are provided to simplify user interaction. The red, blue, and yellow buttons are assigned for solution calibration processes, allowing the system to be adjusted according to predefined reference values. Meanwhile, the green button is dedicated to initiating the sample testing procedure, ensuring a clear separation between calibration and measurement functions to minimize operational errors.

The side view in Fig. 7 illustrates the arrangement of the supporting hardware components required for system operation and maintenance. These components include a power on/off switch for controlling device activation, a charging module port for supplying electrical power to the internal battery system, and a microcontroller communication port used for programming, data transfer, and system debugging. This configuration supports ease of use, reliable power management, and efficient data interfacing, making the device suitable for laboratory and field-based measurement applications.

FIGURE 6. The front panel of the device is equipped with a liquid crystal display (LCD) for presenting measurement results. The red, blue, and yellow push buttons are designated for solution calibration procedures, while the green push button is used to initiate the sample testing proces

FIGURE 6. he side view of the device shows the main hardware interfaces, including the power on/off switch, the

charging module port, and the microcontroller communication port, which are used for device operation, power management, and data interfacing.

B. TESTING PROCEDURE

1) After all testing preparations have been completed, turn on the instrument by pressing the ON/OFF switch.
2) The instrument will initialize, and a menu will appear. Select "pH" to self-calibrate the pH sensor. Perform self-calibration alternately using buffer solutions of pH 4.01, pH 6.86, and pH 9.18. Wait until the results stabilize. Once you have obtained the results, record the test values. Return to the initial menu by pressing the same button. Then select "pH" to self-calibrate the pH sensor. Repeat this step five times for each pH sensor calibration value.
3) Once the pH sensor has self-calibrated, proceed to self-calibrate the TDS sensor. Perform self-calibration alternately using standard TDS solutions of 342 PPM, 500 PPM, and 1000 PPM. Wait until the results stabilize. Once you have obtained the results, record the test values. Return to the main menu by pressing the same button. Then, select "TDS" to self-calibrate the TDS sensor. This step is repeated five times for each TDS sensor calibration value.
4) Once the TDS sensor has been self-calibrated, proceed to self-calibrate the turbidity sensor. Perform self-calibration alternately using standard turbidity solutions of 0 NTU, 10 NTU, and 100 NTU. Wait until the results stabilize. Once you have obtained the results, record the test values. Return to the main menu by pressing the same button. Then select "Turbidity" to self-calibrate the turbidity sensor. Repeat this step five times for each turbidity sensor calibration value.
5) Continue with sample testing by pressing the Sample Test button. Testing is performed using ten types of water. Place the pH and TDS sensors in the chamber and wait for the results to stabilize. Once stable, record the test results. Return the display to the main menu by pressing the same button. Repeat the sample test selection five times for each sample to be tested.

A. TEST RESULTS AND DATA ANALYSIS

The results on Table 1 showed of self-calibration testing on the pH sensor showed that the accuracy value for the standard solution pH 4.01 was 99.25%, the standard solution pH 6.86 was 97.38%, and the standard solution pH 9.18 was 98.69%.

The results of self-calibration testing on Table 2 showed the TDS sensor showed that the accuracy value for the 342 PPM standard solution was 79.65%, the 500 PPM standard solution was 97.20%, and the 1000 PPM standard solution was 98.92%.

The results of self-calibration testing on the turbidity sensor showed on Table 3, that the accuracy value for the 0 NTU standard solution was 100%, the 10 NTU standard solution was 100%, and the 100 NTU standard solution was 100%.

TABLE I
pH SENSOR SELF-CALIBRATION TESTING

Buffer Solution	Test Results					Average	Error (%)	Accuracy (%)
	I	II	III	IV	V			
4,01	3,96	3,93	4,01	4,07	3,91	3,98	0,75	99,25
6,86	6,76	6,65	6,62	6,65	6,72	6,68	2,62	97,38
9,18	9,02	9,06	9,09	9,06	9,09	9,06	1,31	98,69

TABLE II
TDS SENSOR SELF-CALIBRATION TESTING

Solution (PPM)	Test Results					Average	Error (%)	Accuracy (%)
	I	II	III	IV	V			
342	415	410	410	413	410	411,6	20,35	79,65
500	522	513	510	510	515	514	2,8	97,2
1000	984	987	989	992	994	989,5	1,08	98,92

TABLE III
TURBIDITY SENSOR SELF-CALIBRATION TESTING

Solution (NTU)	Test Results					Average	Error (%)	Accuracy (%)
	I	II	III	IV	V			
0	0	0	0	0	0	0	0	100
10	10	10	10	10	10	10	0	100
100	100	100	100	100	100	100	0	100

TABLE IV
CLASSIFICATION OF SAMPLE TESTING

Water Sample	Test Results	Test Results				
		I	II	III	IV	V
VIT	*Turbidity*	1	1	1	1	1
	TDS	166	166	168	168	168
	pH	7,39	7,32	7,25	7,25	7,28
Aquadest	*Turbidity*	1	1	1	1	1
	TDS	0	0	0	0	0
	pH	6,93	7,03	6,82	7,03	7,00
AQUA	*Turbidity*	1	1	1	1	1
	TDS	73	73	73	73	73
	pH	7,43	7,50	7,43	7,40	7,47
Cleo	Turbidity	1	1	1	1	1
	TDS	2	4	4	4	4
	pH	7,20	7,13	7,13	7,16	7,13
Le Minerale	*Turbidity*	0	0	0	0	0
	TDS	4	4	4	4	4
	pH	7,27	7,24	7,22	7,15	7,27
Water Depot "Airku"	*Turbidity*	0	0	0	0	0
	TDS	48	48	48	48	48
	pH	7,05	7,07	7,05	7,15	7,12
Water Depot "Biru"	*Turbidity*	0	0	0	0	0
	TDS	3	3	3	3	3
	pH	7,34	7,32	7,37	7,32	7,37
RO Water Harapan Kita Hospital	*Turbidity*	1	1	1	1	1
	TDS	73	75	75	75	75
	pH	7,33	6,96	6,94	6,96	7,06
RO Water RSCM	*Turbidity*	1	1	1	1	1
	TDS	0	0	0	0	0
	pH	7,23	7,11	7,13	7,06	7,09
RO Water RSUD Pondok Aren	*Turbidity*	1	1	1	1	1
	TDS	0	0	0	0	0
	pH	6,67	6,57	6,60	6,57	6,55
RO Water Premier Bintaro Hospital	*Turbidity*	1	1	1	1	1
	TDS	0	0	0	0	0
	pH	6,84	6,82	6,79	6,82	6,79

From the test results using the water quality measuring instrument module as shown on Table 4, the sample test results for drinking water samples are within the limit values listed according to the Indonesian Minister of Health Regulation Number 492/MENKES/PER/IV/2010 concerning Drinking Water Requirements, namely a maximum turbidity value of 5 NTU, a maximum total dissolved solids (TDS) value of 500 mg/l, and a pH value in the range of 6.5 - 8.5 so that it falls into the category of meeting quality. However, because the module created only uses three parameters among many parameters regarding drinking water health requirements. Therefore, sample test data must still be supported by further testing to ensure that the samples used can truly be said to be suitable for drinking according to the parameters listed in full in the Indonesian Minister of Health Regulation Number 492/MENKES/PER/IV/2010.

IV. CONCLUSION.

The accuracy of the module self-calibration test using standard pH solutions with pH values of 4.01, 6.86, and 9.18 was 99.25%, 97.38%, and 98.69%, respectively.
The accuracy of the module self-calibration test using standard TDS solutions with pH values of 342 PPM, 500 PPM, and 1000 PPM was 79.65%, 97.2%, and 98.92%, respectively.
The accuracy of the module self-calibration test using standard turbidity solutions with pH values of 0 NTU, 10 NTU, and 100 NTU was 100%, 100%, and 100%, respectively.
The 11 samples tested met quality standards. Which means that the drinking water used as a sample is suitable for drinking.

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