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Portable Water Quality Measurement System for Sanitation

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Abstract. Water is one of the essential needs that play an essential role in supporting life on earth. Water for sanitary hygiene purposes is used for several things to maintain individual hygiene, such as bathing and toothbrushes. Water is also for washing foodstuffs, tableware, and washing clothes. In addition, water for hygiene sanitation can be used as raw water for drinking water. This research designs a water quality measurement tool using parameters following water quality for sanitary hygiene purposes issued by the Ministry of Health. These parameters include turbidity, acidity (pH), temperature, and solids in water. The tool is designed to use Arduino Uno as a controller, sensors according to the parameters of photodiode sensors, pH, temperature, TDS (Total Dissolved Solids), and output systems using an LCD 20 × 4. This study concluded that the water quality detection system is running well, using photodiode sensors that can read each level of turbidity based on the value of ADC (Analog Digital Converter). The TDS sensor has an accuracy rate of 93.2% with a 6.8% error percentage. The pH sensor has an occurrence rate of 97.5% with a 2.5% error percentage, and a temperature sensor has an accuracy of 97.84% with a 2.16% error percentage.
Keywords: *Arduino Uno, Photodiode Sensor, pH sensor, Temperature Sensor, TDS Sensor.*

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INTRODUCTION

Water is one of the most important basic needs in living things on earth. Water is used for metabolic processes by living beings. In humans, the function of water is a necessity for industry, agriculture, transportation, and much more. There are three sources of water on this earth, namely groundwater, surface water, and rainwater. Groundwater is water that is in the soil layer at different depths. Humans usually use groundwater for life needs, for example, obtained through wells or water pumps [1]. The physical condition of clean water must be clear, odorless, and tasteless [2] in the Regulation of the Minister of Health of the Republic of Indonesia number 32 of 2017 Chapter II on the standard of environmental health quality standards for sanitary hygiene purposes. Environmental health quality standards for sanitation hygiene water include several physicals, biological and chemical parameters [3].

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Murky water is a characteristic of unhealthy water. Turbidity is an optical property determined by light absorbed and emitted by the solution contained in water. Water can be said to be cloudy when the water has a particle charge of suspended material, thus sharing a muddy and dirty color or appearance. The materials that cause this turbidity include clay, mud, fine sand, and organic materials [5].

Acidity or pH of water is also very influential for our metabolism because if the water we consume to drink and processed foods have a low pH, the needs in our body don't meet to the maximum. Good water for consumption following the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 has a pH value of 6.5 – 8.5. As for the water, the temperature should be cold (not hot), primarily so as not to occur dissolving chemicals can harm health. The temperature parameter for sanitary hygiene water is the air temperature ± 3 [3].

Total Dissolved Solids, often abbreviated to TDS, measure dissolved organic and non-organic, e.g., salts and the like contained in water, ionized or in the form of micro granules (collide soles) are trapped. TDS is used to guide water characteristics and as an aggregate parameter of the comprehensive measurement of chemical pollution [6]. The high value of solids or TDS is one of the considerations in determining water quality for use in households. Parameters in TDS measurement provided that the result does not exceed 1,000 mg/l [3]. In previous studies, a water quality detection device has been developed with three parameters, namely PH, TDS, and Water Temperature [4]. In this study, there are differences from the previous tool has four parameters, namely turbidity, PH, TDS, and water temperature. This article describes its application to several water sources in rivers. This tool can determine the quality of water for household needs

RESEARCH METHODOLOGY

Research Equipment

The equipment in this study used two types of devices, namely hardware, and software. Components and tools used in hardware include Silicon Photodiode Sensor [7][8][9], PH-4502C pH Sensor [10][11], Gravity Sensor TDS [14][15], DS18B20 Temperature Sensor [12][13], Arduino Shield Sensor, Arduino Uno, 4.7k resistor Ω, male-female cable, Project Board, Glass Cuvette, Liquid Crystal Display (LCD) 20 × 4, Laptop, Push Button and Plastic Box. While the software used is IDE Arduino and Fritzing. At the same time, the tool for calibration uses tools from the factory, such as TDS-3 and PH 009(I) A.

Stages and Flow of Research

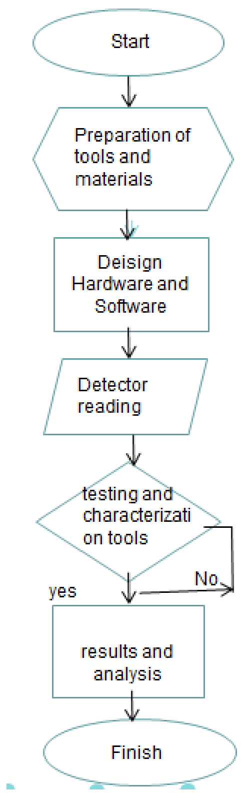

Figure 1 Stages and Flow of Research.

The hardware design of each water quality measuring instrument for sanitary hygiene purposes, each sensor is connected to the Arduino Uno control system. For turbidity measurement, added blue LED components can be seen in figure 2 Hardware Design.

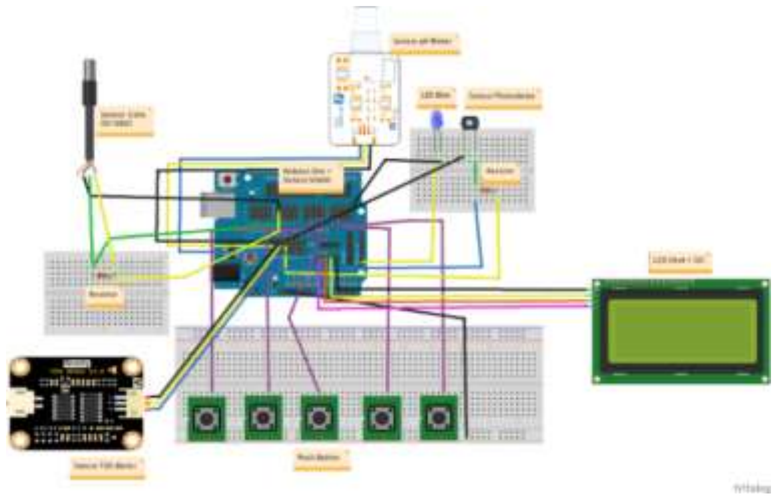

Figure 2 Hardware Design.

In Figure 2 of the Hardware Design, five pushbuttons are pressed to create a menu section inside the program displayed to the LCD output. Furthermore, use the Arduino shield sensor to reduce jumper cables on the circuit. Arduino IDE is the software

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used for water quality measuring equipment for hygiene sanitation purposes. Arduino receives readings from Photodiode sensors, pH sensors, DS18B20 temperature sensors, and TDS sensors. Therefore Arduino must be filled with a program in the form of source code, then Arduino will process the reading results and output the results on the LCD 20 × 4.

Data Retrieval

The data retrieval method is obtained by conducting two stages of testing, among others, sensor calibration testing by calibrating the tool with the factory output tool, then each sensor is set in the Arduino IDE for voltage output. After getting linear regression to go into the second stage. The second stage is testing the accuracy of each sensor with several sample options for each sensor.

Data Processing

The data obtained will be processed using the linear regression method, standard deviation, and percentage error value. The following are linear regression formulas and deviation standards:

$$Linear\ Regression\ Formula\ is\ y = bx + a \quad (1)$$

$$s = \sqrt{\frac{n\sum_{i=1}^{n} x_1^2 - (\sum_{i=1}^{n} x_1)^2}{n(n-1)}} \quad (2)$$

The formula of the percentage error value of the sanitary hygiene water quality measuring instrument is:

$$\%\ error = \frac{|\ test\ value - theoretical\ value\ |}{theoretical\ value} \times\ 100 \quad (3)$$

River water data collection method

River water samples were taken from 6 different places. Three water samples were taken for each place. Each water sample contains 100 ml. Water sample testing carried out in the form of turbidity, TDS, PH and temperature.

In this study, testing was carried out in accordance with SNI 06-6989.11-2004. This method includes, how to test the degree of acidity (Ph) of water and wastewater using a pH meter. In addition, referring to SNI 06-6989.23-2005 the test is used to determine the temperature of water and wastewater using a mercury thermometer compared to the tool made.

RESULTS AND DISCUSSION

In designing sanitary hygiene water quality measuring instruments, researchers conducted two design stages, namely hardware and software. The following are the results of hardware and software design:

(a) (b)

Figure 3 Design results (a) Outer view and (b) Inward view.

The results of hardware design in this study include the design of water quality measuring instruments for sanitary hygiene purposes using four parameters: turbidity, pH, TDS, and temperature. The output of each parameter is the turbidity shown by the division of levels in the Analog to Digital Converter (ADC) value that converts analog inputs into digital codes [16], for acidity or pH, the output value is pH, the output on the TDS is ppm, and the output for the temperature is °C. The value in the output successfully performs the software design by entering the source code by the Arduino IDE.

Figure 4 Output results on LCD.

Data Processing and Results

Accuracy testing is performed on several test samples at different levels of each parameter unit. Moreover, there are six samples from different locations for the tool test as a whole. Sensor accuracy testing compares factory output gauges with designed gauges controlled by Arduino Uno.

Table 1 Data processing to determine the level of turbidity in photodiode sensors

No	Turbidity Level	ADC Value
1	Clear	>155
2	A Little Murky	>120
3	Quite Murky	>90
4	Murky	>50
5	Very Murky	>5

In Table 1 of Data processing to determine the level of turbidity on photodiode sensors, the level of turbidity for clear is obtained if the ADC value is more than 155, for a slightly cloudy if the ADC value is more than 120, for somewhat murky ADC values over 90, for murky ADC values over 50 and for very murky ADC values over 5.

Table 2 Processing of comparative value data between pH sensor and factory pH meter.

No.	Materials	Time Duration (minutes)	Average Sensors PH-4502C (pH)	PH-009(I)A (pH)	Standard Deviation	Percentage Error (%)
1	phosphoric acid	± 3	2.08	2.10	0.021	0.90
2	phosphoric acid	± 3	2.70	2.80	0.007	3.50
3	phosphoric acid	± 3	3.93	4.00	0.013	1.75
4	phosphoric acid	± 3	6.25	6.50	0.027	3.80
5	NaOH	± 3	7.53	7.80	0.011	3.40
6	NaOH	± 3	9.65	9.80	0.022	1.50
7	NaOH	± 3	10.10	10.40	0.176	2.70
8	NaOH	± 3	11.20	11.50	0.187	2.60
Average Standard Deviation					**0.058**	
Average Percentage Error					**2.500**	
Accuracy (100 % - Percentage Error)					**97.500**	

In processing pH sensor data, first, to determine the type of sample for the test, the sensor measurement is then carried out starting with an acid solution and then to the base and taken measurement using pH meter afterward. The results of the eight measurements of phosphoric acid and NaOH liquids, both of which were added, obtained an average percentage of errors of 2.5% and the accuracy value of the tool 97.5%. The standard deviation average is 0.058, as shown in Table 2 of the data processing of the comparison value between the pH sensor and the factory meter pH. This percentage of errors is caused by sensor sensitivity, reference pH, and ADC conversion.

Table 3 Data processing value comparison between TDS sensor with the factory TDS meter.

No.	Time Duration (seconds)	Average Sensors Gravity TDS (ppm)	TDS-3 (ppm)	Standard Deviation	Percentage Error (%)
1	± 5	0.00	0	0.00	0.00
2	± 5	16.40	18	2.30	8.80
3	± 5	21.40	24	2.07	10.80
4	± 5	30.80	34	1.60	9.40
5	± 5	39.20	45	1.30	12.80
6	± 5	43.40	49	2.90	11.40
7	± 5	69.20	72	0.44	3.80
8	± 5	140.20	146	0.44	3.90
9	± 5	206.40	208	0.54	0.70
Average Standard Deviation				**1.3**	
Average Percentage Error				**6.8**	
Accuracy (100 % - Percentage Error)				**93.2**	

In processing TDS sensor data, first, to determine the type of sample for the test, the subsequent measurement of the TDS meter begins with mineral water coupled with kitchen vinegar. Furthermore, measurements are performed using the TDS sensor afterward. The eight measurements of mineral water liquid added with kitchen vinegar obtained an average percentage of errors of 6.8% and the accuracy value of the tool 93.2%. The standard deviation average is 1,303, as shown in table 3 data processing of the comparative value between the TDS sensor and the factory meter TDS. This percentage of errors is caused by sensor sensitivity, reference TDS meter, mineral location in water, and ADC conversion.

Table 4 Processing of comparative value data between the Temperature sensor and factory meter temperature

No.	Time Duration (seconds)	Average Sensors DS18B20 (temperature °C)	TDS-3 (temperature °C)	Standard Deviation	Percentage Error (%)
1	± 15	26.60	28	1.10	5.50
2	± 15	36.40	36	0.90	1.10
3	± 15	53.80	54	1.30	0.30
4	± 15	62.20	62	0.83	0.30
5	± 15	23.20	23	1.30	0.80
6	± 15	20.60	22	1.50	6.30
7	± 15	18.20	18	1.30	1.10
8	± 15	30.40	31	1.10	1.90
Average Standard Deviation				**1.10**	
Average Percentage Error				**2.16**	
Accuracy (100 % - Percentage Error)				**97.84**	

In the calibration test process of the temperature sensor, first to determine the type of sample for the test, then conducted temperature measurement with TDS meter starting with cold water, regular water, and hot water. Furthermore, measurements are performed using the temperature sensor afterward. The eight measurements obtained an average error percentage of 2.16% and a tool accuracy value of 97.84%. The average standard deviation is 1.1. This error percentage is caused by sensor sensitivity, reference meter TDS, probe position in the water, and ADC conversion.

Table 5 Overall test of tools with multiple locations

Location	Turbidity	TDS (ppm)	pH	Temperature (°C)
Jonggol, West Java	Clear	110	6.63	25.56
Cimande, West Java	Clear	47	7.41	25.25
Cikarang, Jababeka I	Clear	163	6.33	25.50
Cikarang, Jababeka II	Clear	134	6.45	25.69
Cimande River, West Java	Quite Murky	43	6.37	25.25
Chemical Plant Waste, Cikarang	Murky	348	5.95	25.31

The overall test results of the tool were obtained that the tool has worked in measuring the TDS, turbidity, pH, and temperature of various test samples. Measurement results in six locations showed TDS ranged from 43 ppm to 348 ppm, with all locations meeting the TDS parameter that does not exceed 1000 ppm. Location turbidity measurement results in 5 and 6 are not eligible with parameters created using Analog-Digital Converter (ADC). The pH measurement results are only locations 1 and 2 that meet the 6.5 pH – 8.5 pH standard. Moreover, all locations meet the standard of clean water parameters for the temperature measurement results, i.e., air temperature ± 3 °C [3].

CONCLUSION

The Measurement System of Turbidity, Acidity Level (pH), Temperature, and number of Dissolved Solids in Water using a photodiode sensor, Analog pH Sensor PH-4502C, Temperature Sensor DS18B20 Waterproof and Gravity Analog TDS Sensor SKU: SEN0244 was successfully designed and built. The accuracy and calibration of each sensor showed the TDS sensor has an accuracy rate of 93.2% with a 6.8% error percentage, the pH sensor has an acceptance rate of 97.5% with a 2.5% error percentage, and a temperature sensor has an accuracy of 97.84% with a 2.16% error percentage. The test carried out proved that this tool has worked in measuring TDS, turbidity, pH, and temperature. Measurement results in six locations showed TDS ranged from 43 ppm to 348 ppm, with all locations meeting TDS parameters not exceeding 1000 ppm. Location turbidity measurement results in 5 and 6 are not eligible with parameters.

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