

Design of pH Measuring Equipment for Liquid Waste from Coal Mining Using Arduino Uno

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Abstract— In coal mining, to check the pH content of the water in the liquid waste from coal mining, most of the mining workers use conventional methods, namely by measuring using a digital pH meter or litmus paper periodically. Manual pH reading system makes handling slow. Based on these reasons the researchers designed a tool that can monitor pH values, the working principle of this tool is that the pH electrode is inserted into the sample solution, then the electrode detects the sample solution and changes the electrical signal, where the output will be amplified by an amplifier circuit in the form of an analog voltage, then on Arduino uno analog data is converted to digital data or ADC (Analog To Digital Conversion) after which it is converted again to pH value and displayed on an LCD that has been equipped with I2C. And this tool is also equipped with an RTC (Real Time Clock) so that it can display the time at which pH data is taken in the waste. The results of the calibration of the pH sensor obtained a linear equation, namely, $Y = 25.84 - 7.1211X$ so that the designed tool has an error percentage of the manufacturer's pH meter tool of 1.028 %. By using this tool, the writer concludes that 0.4 grams of camphor (CaO) on the prototype or 480 kg in real conditions with a pool area of 600 m³ can reduce the output voltage on the pH sensor from 3.20 V to 2.56 V thereby increasing the pH value. from 3.07 to 7.58 in pool 4 or drain pool.

Keywords— ADC, Arduino Uno, coal waste, camphor (CaO), pH, voltage.

I. INTRODUCTION

Coal mining is an industry that provides many advantages for our country, including meeting domestic needs and increasing the country's foreign exchange.

However, the existence of coal mining is often not accompanied by good handling of the waste [10].

Environmental pollution by coal mining waste is something that must be considered properly and handled quickly, precisely and correctly. So in this final project the author will design a tool that can monitor the pH levels of the liquid waste in order to identify whether the nature of this liquid waste has met the eligibility requirements, if not, it must get the right handling so that there is no pollution and damage to the surrounding environment such as giving camphor to the environment. waste so that the acidic nature of the water can be neutralized. Previously this tool already existed but only measured manually and the price of the measuring instrument was quite expensive. And this tool can be used to monitor the quality of coal liquid waste in real time with a predetermined data collection time.

The working principle of this tool is to convert the voltage into a pH value with an input voltage of 5 Volts from a solar cell power supply or 9 V battery. This tool uses an Arduino Uno with microcontroller technology, which is a complete microprocessor system contained on an IC chip. (Integrated Circuits) which is open source. So that the microcontroller is often called a microcomputer which is used by entering commands according to the needs needed using a software to write the commands. In this thesis the author will also explain the algorithm system of the tool design. With this tool is expected to reduce the work to measure quality standards manually to be automatic.

A. PH sensor

In principle, the measurement of a pH is based on the electrochemical potential that occurs between the solution contained in the known glass electrode (glass membrane) and the unknown solution outside the glass electrode. This is because a thin layer of glass bubbles will interact with hydrogen ions which are relatively small and active, the glass electrode will measure the electrochemical potential of hydrogen ions or termed the potential of hydrogen. The pH sensor will measure the electric potential between mercury chloride (HgCl) at the reference electrode and potassium chloride (KCl) which is a solution in the glass electrode and the potential between the solution and the silver electrode. [7].



Fig. 1. PH sensor [7]

B. Arduino

Arduino is an electronic kit or open-source electronic circuit board in which the main component is a microcontroller chip with the AVR type from the Atmel company. The microcontroller itself is a chip or IC (Integrated Circuit) that can be programmed using a computer. The purpose of embedding the program on the microcontroller is so that the electronic circuit can read the input, process and output of an electronic circuit [4].

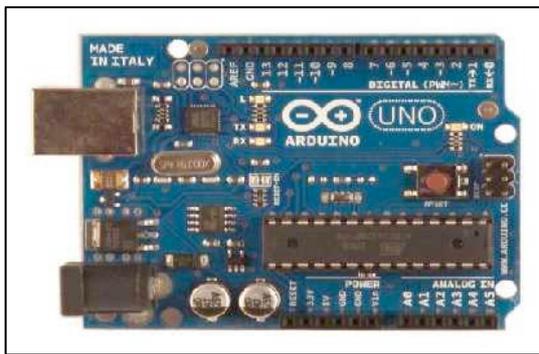


Fig. 2. Arduino UNO [4]

C. Analog to Digital Converter (ADC).

ADC (Analog to Digital Converter) is an electronic device that functions to convert analog signals (continuous

signals) into digital signals. The ADC (Analog to Digital Converter) device can be in the form of a module or electronic circuit or an IC chip. ADC serves to bridge the analog signal processing by digital systems [11]. The working principle of the ADC is to convert the analog signal into the form of a quantity which is the ratio of the input signal to the analog voltage and the system voltage can be found using equation 1 below [11].

$$ADC\ Value = \frac{ADC\ Resolution}{V_{ref}} \times V_{in} \quad (1)$$

ADC consists of several types, one of which is the SAR (Successive Approximation Register) ADC. The following is a picture of the ADC SAR seen in Figure 3.

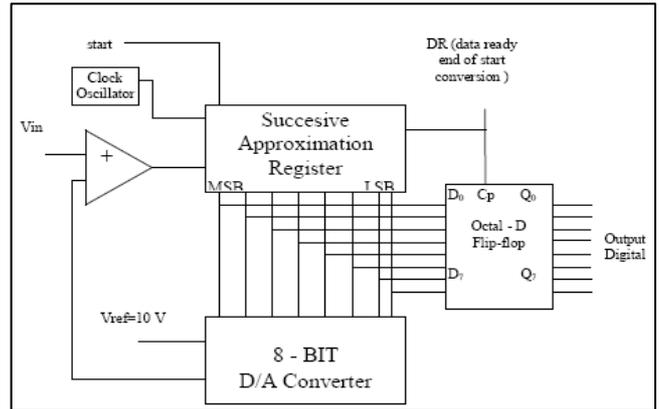


Fig. 3. ADC SAR Block Diagram [3]

Figure 3 shows an ADC diagram of the SAR type, namely by using a configuration that is almost the same as the Counter Ramp but in tracing by tracking by issuing a combination of bits MSB = 1 such as 1000 0000. If it is not the same (less than the analog input voltage then the next MSB bit = 1 is like 1100 0000) and if the analog input voltage is smaller than the voltage generated by the DAC, the next step is to reduce the bit combination to 10100000. For example, given an analog input voltage of 6.84 Volts and an ADC reference voltage of 10 Volts so that if the output voltage is as follows [3]:

- If D7 = 1 $V_{out} = 5\text{ Volt}$
- If D6 = 1 $V_{out} = 2.5\text{ Volt}$
- If D5 = 1 $V_{out} = 1.25\text{ Volt}$
- If D4 = 1 $V_{out} = 0.625\text{ Volt}$
- If D3 = 1 $V_{out} = 0.3125\text{ Volt}$
- If D2 = 1 $V_{out} = 0.1625\text{ Volt}$
- If D1 = 1 $V_{out} = 0.078125\text{ Volt}$
- If D0 = 1 $V_{out} = 0.0390625\text{ Volt}$.

II. METHOD

A. Simple Linear Regression Software Design

Simple linear regression equation is an equation model that describes the relationship of one independent variable/predictor (X) with one dependent variable/response (Y), which is usually depicted by a straight line, as presented in Figure 4 [4].

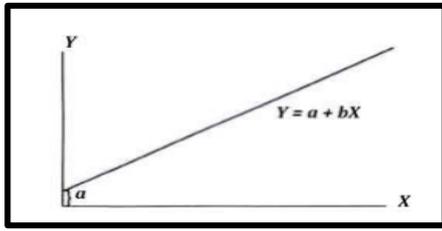


Fig. 4. Illustration of Linear Regression Line [4]

The simple linear regression equation is mathematically expressed as follows [8]:

$$Y = a + bX \quad (2)$$

Where:

- Y = regression line/ response variable
- a = constant (intercept)
- b = regression coefficient (slope)
- X = independent variable/ predictor

The value of the constant (a) and the regression coefficient (b) can be determined using the following equation [8]:

$$a = \frac{(\sum Y)(\sum X^2) - (\sum X)(\sum XY)}{n(\sum X^2) - (\sum X)^2} \quad (3)$$

$$b = \frac{n(\sum XY) - (\sum X)(\sum Y)}{n(\sum X^2) - (\sum X)^2} \quad (4)$$

where n = number of data

B. Tool Design

Here is a picture of the circuit of all the components of the tool, which can be seen in Figure 5.

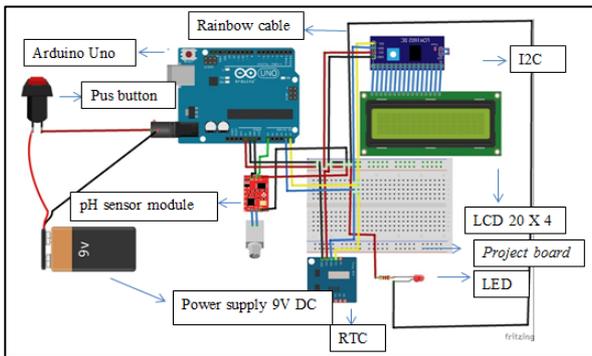


Fig. 5. Circuit of pH Level Measurement Tool Based on Arduino Uno

Figure 5 shows a series of all components consisting of Arduino Uno, pH sensor module, RTC, push buttons, LED lights, jumper cables (rainbow cables), Project board, 20x4 LCD and I2C modules which are soldered directly on the LCD. The pH sensor module has 3 pins connected to the Arduino, namely the VCC pin connected to the Arduino 5V VCC, the GND pin connected to the Arduino GND, and the PO pin as the output of the pH sensor which is connected to the analog pin on the Arduino Uno, namely pin A0.

The RTC has 4 pins connected to the Arduino Uno, namely the VCC pin to the Arduino VCC, the GND pin to the Arduino GND, the SDA pin to the Arduino A4 and the SCL pin to the Arduino A5. And there are four pins that are

used to turn on an LCD, the four pins on the I2C LCD include VCC, GND, SDA and SCL, the Arduino VCC pin is connected to the I2C LCD VCC pin, the Arduino GND pin is connected to the I2C LCD GND pin, the SDA pin on the Arduino connected to the SDA LCD I2C pin, the Arduino SCL pin is connected to the I2C LCD SCL pin. The following is the shape of the tool that has been designed, as shown in Figure 6.

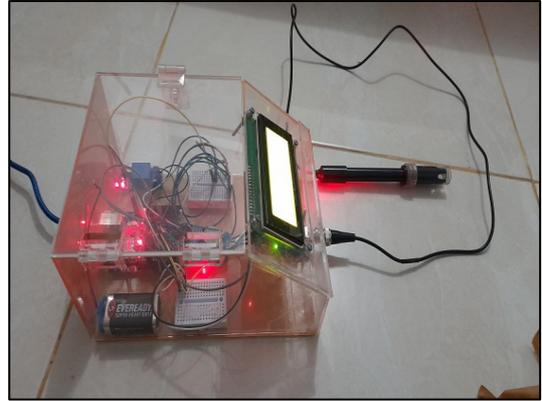


Fig. 6. Tools that have been designed

C. F. Calibration of pH Sensor with Linear Regression Method

The pH sensor calibration test is carried out by comparing the pH meter value and the pH sensor output voltage obtained, so as to obtain a linear regression equation, this test uses 4 samples for data collection.

where :

X : Variable Factor (Voltage sensor value)

Y : Response Variable (Factory-made pH meter value)

TABLE I. CALCULATION OF LINEAR REGRESSION PH VALUE

No	x (Volt)	y (pH)	x ²	y ²	xy
1	2.64	6.9	6.9696	47.61	18.216
2	3.05	4.1	9.3025	16.81	12.505
3	2.84	5.7	8.0656	32.49	16.188
4	2.53	7.9	6.4009	62.41	19.987
Σ	11.06	24.6	30.7386	159.32	66.896

Calculating Constant (a) determined determined using Equation 3:

$$a = \frac{(\sum Y)(\sum X^2) - (\sum X)(\sum XY)}{n(\sum X^2) - (\sum X)^2}$$

$$a = \frac{(24.6)(30.7386) - (11.06)(66.896)}{4(30.7386) - (11.06)^2}$$

$$a = 25.84$$

Calculating Constant (b) determined determined using Equation 4:

$$b = \frac{n(\sum XY) - (\sum X)(\sum Y)}{n(\sum X^2) - (\sum X)^2}$$

$$b = \frac{4(66.896) - (11.06)(24.6)}{4(30.7386) - (11.06)^2} = -7.1211$$

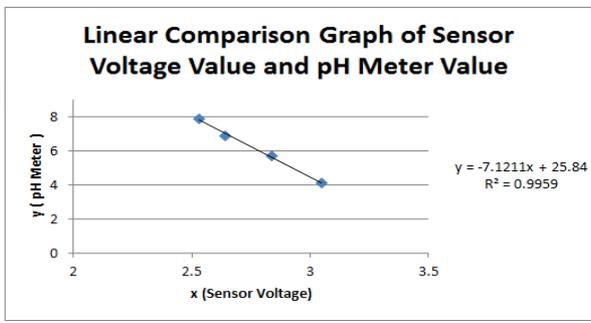


Fig. 7. Linear Comparison Graph of Sensor Voltage Value and pH Meter Value

Then the results of the calibration of the voltage and pH meter get a linear regression equation by entering the value of the constant (a) and the regression coefficient (b) in Equation 2 as follows:

$$Y = a + bX$$

$$Y = 25.84 - 7.1211X$$

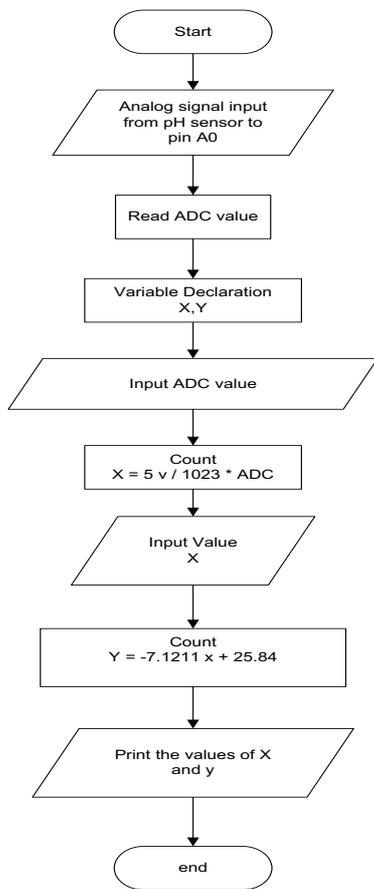


Fig. 8 Flowchart of Tool Design Algorithm

The algorithm system in question is a work system on the electrical design of the tool from the output on the pH sensor in the form of a voltage (analog signal) which will be forwarded to the Arduino Uno. On Arduino Uno the voltage value will be converted into a digital value with a resolution of 10 bits and then converted again into a pH value, and the data from Arduino Uno will be displayed on the LCD.

D. Tool Design Algorithm

The following is the tool design algorithm system which will be explained using a flowchart in Figure 8.

III. RESULTS AND DISCUSSION

A. Tool Validation Test

The purpose of this test is to make sure the tool is working by displaying valid data by comparing the output value of the factory-made pH meter with a tool that has been designed by the author, this test uses a solution whose pH value is known, namely a buffer solution of pH 4 and pH 7, and solutions whose pH value is not known, such as well water, mineral water, and detergent water.

TABLE II. TOOL VALIDATION TEST RESULTS

No	solution	Sensor pH Output	pH Meter Tool Output	Error %
1	Buffer pH 7	6.94	6.88	0.872
2	Buffer pH 4	4.10	4.06	0.985
3	Well water	5.67	5.73	1.047
4	Mineral water	7.74	7.64	1.309
5	Detergent water	8.55	8.63	0.927
Average				1.028

Table II shows the comparison of the results of pH measurements using a design tool with a manufacturer's tool, namely a pH meter, almost the same results are obtained, with an average percentage error of 1.028.

B. Coal Waste pH Test

Tests carried out on one of the coal wastes in Riau, Indonesia. This test is carried out to determine the pH value in the monitoring aspect in the field. The test was carried out for two days, the first day was carried out in the afternoon and the second day was carried out in the morning.



Fig. 9. PH reading in the Coal Waste Reservoir Pond

The following is the data obtained for two days of pH reading, which can be seen in Table III.

TABLE III. PH TESTING ON COAL WASTE IN MONITORING ASPECT

No	Date	Time	Voltage (V)	pH
1	05-07-2021	15.00	2.82	5.79
2		15.30	2.81	5.80
3		16.00	2.82	5.74
4		16.30	2.81	5.81
5		17.00	2.82	5.77
6	06-07-2021	07.00	2.84	5.64
7		07.30	2.85	5.56
8		08.00	2.84	5.61
9		08.30	2.84	5.59
10		09.00	2.83	5.67
11		09.30	2.83	5.68
12		10.00	2.82	5.74
13		10.30	2.82	5.77
14		11.00	2.83	5.71
Average			2.827	5.71



Fig. 11. The Process of Reading the pH Value of Each Pond

The following is a graphic image of the reading of pH values in waste in the field, which can be seen in Figure 10.

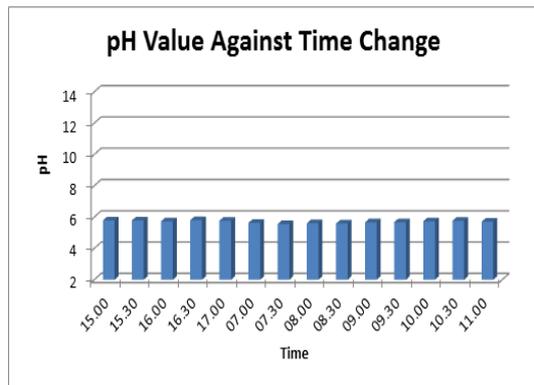


Fig. 10. Changes in pH Value with Time

In the above test, it can be seen in the graph of changes in pH levels over time that are close to constant with an average pH reading of 5.71. It can be said that the waste is in an acidic state, so it needs to be handled such as giving camphor so that the pH is declared neutral or safe.

C. Testing the pH of Camphor Treatment Using Coal Waste Pond Prototype

After doing the above test, the author will test the pH value of each pond against the amount of camphor given to the waste. For the dose of camphor in this study, namely with doses of 0 g, 0.1 g, 0.2 g, 0.3 g and 0.4 g into the prototype pond that already contains coal waste. After adding camphor to the wastewater, wait a few minutes until the stirring process occurs in the prototype of the coal waste pool, when it is mixed evenly the author will read the pH value of each pool, if the pH is still below 6 then add another dose of camphor to the pH value. goes up and reads 6 – 9. In Figure 11 it can be seen the process of reading the pH value of each pond that has been given camphor.

The following is the data on the results of pH testing for camphor application, which can be seen in Table IV.

TABLE IV. PH TEST RESULTS AGAINST CAMPHOR

Camphor (g)	Time	Pond 1		Pond 2	
		V	pH	V	pH
0	20.30	3.20	3.02	3.20	3.00
0.1	21.15	3.07	3.95	3.08	3.92
0.2	22.00	2.95	4.82	2.95	4.81
0.3	23.30	2.77	6.09	2.77	6.10
0.4	00.40	2.56	7.61	2.55	7.65
Camphor (g)	Time	Pond 3		Pond 4	
		V	pH	V	pH
0	20.30	3.20	3.03	3.20	3.07
0.1	21.15	3.08	3.91	3.08	3.91
0.2	22.00	2.95	4.82	2.95	4.83
0.3	23.30	2.78	6.06	2.78	6.02
0.4	00.40	2.56	7.63	2.56	7.58

It can be seen in the table above that camphor can affect changes in the voltage on the pH sensor which will cause the pH value to change. The following is a Cartesian diagram of changes in pH value to camphor application, which can be seen in Figure 12.

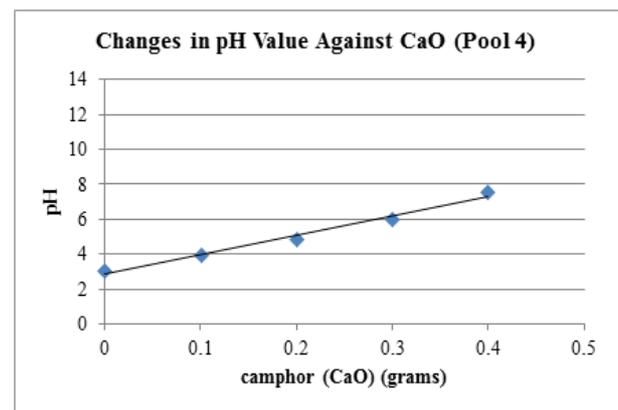


Fig. 12. Changes in pH Value to Camphor stone (Pool 4)

It can be seen in the graph in Figure 12 where the pH value of the wastewater in pond 4 will change when camphor is added with an average change in pH for each addition of 0.1 grams of camphor is 1.128. So, in the above test the authors found that the more camphor is given to the waste, the lower the output voltage of the pH sensor so that the acidity value is lower, or the pH value will be read higher. With the addition of 0.1 grams of camphor into the waste, it is found that in pond 4 or the disposal pond the average change in pH is 1.128. So, in this test it will take 0.4 grams of camphor to reduce the output voltage on the pH sensor from 3.20 V to 2.56 V so that it increases the pH value from 3.07 to 7.58 and can be said to be safe.

IV. CONCLUSION

The results of the calibration of the tool obtained a linear equation, namely $Y = 25.84 - 7.1211X$. The tool designed has a large level of accuracy due to the error percentage of the pH sensor of 1.028%. The pH value will be inversely proportional to the voltage and ADC values, the greater the voltage generated by the pH sensor, the smaller the pH value displayed, as well as the ADC value, the greater the ACD value, the smaller the pH value. The change in pH value in coal liquid waste for two days is close to constant with an average pH reading of 5.71, so the waste is said to be in an acidic state. Camphor affects the output voltage value of the pH sensor, so the more camphor (CaO) is applied to the waste, the smaller the voltage produced by the pH sensor will increase the pH value, with 0.4 grams of camphor (CaO) can reduce the output voltage on the sensor pH from 3.20 V to 2.56 V thus increasing the pH value from 3.07 to 7.58. Giving camphor (CaO) as much as 0.1 grams or in the condition of the original waste pool by giving 120 kg of camphor, the pH value will increase in the disposal pool (pool 4) by 1.128, which is obtained by comparing the data using the prototype.

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