Measurement of water polluted quality based on turbidity, pH, magnetic property, and dissolved solid

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Abstract. A device of polluted water measurement based on turbidity, pH, dissolved Solids, and magnetic field parameters, has been developed. The device consists of three light dependent resistor (LDR) sensors as turbidity detector, conductivity sensor as total dissolved solids (TDS) detector, SKUSEN0161 pH sensor as pH detector, Hall Effect magnetic sensor as a magnetic field detector and Arduino as a control system. Each sensor has been characterized using a standard measuring instrument to determine sensor sensitivity. Sensitivity of the LDR sensor are 102.64 NTU/V, 117.53 NTU/V, and 126.394 NTU/V. Meanwhile, sensitivity of conductivity sensor is 102.5 ppm/V, pH sensor is 3.5069 pH/V, and Hall Effect sensor is 303.21 Gauss/V. The samples used in prototype trials are polluted water samples, magnetized water sample, and artificial waste sample. The magnetized solution sample used in pH observation are acidic water, turbid river water, and alkaline water. Meanwhile, the magnetized solution sample used in TDS & turbidity observation is river water contaminated by household wastes. The results show there is a correlation between the four parameters. By applying the magnetic field in a certain time interval, the turbidity and TDS of the sample decrease, in the contrary the pH value of the sample increases.

1. Introduction
The decline in water quality due to pollutants of various human activities, such as residential, industrial, fertilizing and pesticide waste, has become one of the major environmental issues. River water quality in 918 sample points of 122 rivers in Indonesia, shows that 68 percent of river water conditions categorized as heavily polluted. As most of the domestic waste produced has not been processed and immediately discharged into the river [1]. Thus, it is necessary to make efforts of overcoming pollution, through monitoring and interpretation of water quality data that covers the quality of physics, chemistry and biology in accordance with the desired level of quality. Physical quality is determined by parameter of electric conductivity, dissolved solids, thermal conductivity, viscosity, turbidity, etc.

According to the Republic of Indonesia Ministry of Health regulations, Consumable water must satisfy several requirements, that are turbidity must not be more than 5 NTU, inorganic ingredients must have a total dissolved solids (TDS) value below 500 ppm and pH between 6.5 - 8.5. Other parameter influences water quality is magnetic fields. Magnetic field helps water purification process
and reduces water density by 51% [3]. The water magnetization process affects the parameters of pH, TDS [4], electrical conductivity [5], refractive index [6], viscosity, surface tension [7], and thermal conductivity [8]. This paper describes the development of water quality measurement systems with parameters of turbidity, pH, total dissolved solids and magnetic fields.

2. Experimental

The developed device consists of 3 LDR sensors as a turbidity detector, a pH sensor SKUSEN0161 as a pH detector, conductivity sensor for detecting the quantity of dissolved solids, and a magnetic sensor UGN3503 as a magnetic field detector. The measurement information will be processed by Arduino and displayed by a 16x2 LCD.

To determine the accuracy and measurement range of the sensor, each sensor is characterized and calibration using a standard tool. LDR Sensor was calibrated by comparing the output voltage of the LDR sensor to the turbidity measurement of turbidimeter DR 900. The pH sensor is calibrated by comparing the results of the pH sensor output voltage to the measurement results of pH meter 009 (I) A. Calibration of the conductivity sensor by comparing the sensor output voltage to the measurement result of conductivity meter type SKU: PE4000CN. Meanwhile, calibration of the Effect Hall sensor uses a calibration coil, diameter of 5.6 cm and the number of turns 740, as a source of artificial magnetic field. The solution samples of turbidity and TDS calibration are presented in Table 1, and solution samples of the pH sensor are presented in Table 2. Prototype trials were carried out on polluted water samples, magnetized water sample, and artificial waste sample.

| No | Sample                          | No                     | Sample                                  |
|----|--------------------------------|------------------------|-----------------------------------------|
| 1  | Filtered river water            | 6                      | Filtered river water + sand of 4 tsp    |
| 2  | Filtered river water + sand of 0.5 tsp | 7                  | Filtered river water + sand of 5 tsp    |
| 3  | Filtered river water + sand of 1 tsp | 8                  | Filtered river water + sand of 6 tsp    |
| 4  | Filtered river water + sand of 2 tsp | 9                  | Filtered river water + sand of 7 tsp    |
| 5  | Filtered river water + sand of 3 tsp | 10                 | Filtered river water + sand of 8 tsp    |

Table 1. The solution samples of turbidity and TDS calibration

| No | Sample    | No | Sample                  |
|----|-----------|----|-------------------------|
| A  | pH of powder 9.18 | F  | toner water             |
| B  | pH of powder 4.01 | G  | lemon water             |
| C  | Powder pH 6.86 | H  | distilled water         |
| D  | lime juice water | I  | bath soap water         |
| E  | laundry soap water | J   | ulcer medicine water    |

Table 2. The solution samples of pH sensor calibration

3. Results and Discussion

3.1. Sensors Characterization

The characteristic curve of the six sensors is shown in Figure 1. Sensitivity (S) of each sensor, which is the ratio of the output signal changes to input signal changes, can be calculated through the equation (1). Therefore, the relative error of the sensor is calculated using the equation (2).

\[ S = \frac{\Delta \text{output}}{\Delta \text{input}} \]  (1)

\[ \text{Relative error} = \frac{|PS - PL|}{PL} \times 100\% \]  (2)

Wherein PS is the measured value of the sensor, and the PL is the actual value measured by laboratory or standard equipment.

Figure 1a appears that turbidity is inversely proportional to the sensor output voltage, the greater the turbidity value the sensor output voltage gets smaller. LDR 1, LDR 2, and LDR 3 sensor has different slopes, so the sensitivity of each is different, that are 102.64 NTU/V, 117.53 NTU/V, and 126.39 NTU/V respectively. Relative measurement error of each sensor is 1.68%, 4.68%, and 8.75%. In the other hands, Figure 1b, 1c and 1e have a positive slope, the sensor output voltage is proportional
to the measurement using laboratory equipment. According to equations 1 and 2, the sensitivity of the pH sensor, conductivity sensor, magnetic sensor is 3.5069 pH/V, 102.5 ppm/V, 303.21 G/V, and the relative measurement error the sensitivity of the pH sensor, conductivity sensor, magnetic sensor is 1.585%, 0.32%, and 1.987%.

Figure 1. Sensor Characterization (a) LDR sensors (b) pH sensor (c) Conductivity sensor (d) Magnetic sensor

3.2. Prototype experiment
Prototype experiment is performed to find out whether the system has a good function or not. The experiment was carried out by measuring 1 sample by the whole sensor simultaneously. Four water samples taken from different rivers were used in this experiment, each sample has 100 ml of water volume. The measurement results are shown in Table 3. It was seen that the prototype able to measure all four parameters, and able to distinguish different characteristics of the four samples. The characteristics of each sample are influenced by type of pollutant in water. The sample of river water contaminated by household waste has highest magnetic field and TDS.

| Sample                                      | Magnetic Field (Gauss) | pH (pH)  | Turbidity (NTU) | TDS (ppm)  |
|---------------------------------------------|------------------------|----------|-----------------|------------|
| River water contaminated by household waste | 8.89                   | 7.20     | 25.64           | 182.29     |
| River water polluted by beverage factory waste | 4.44                   | 4.01     | 56.44           | 167.76     |
| Kalimalang river water                      | 2.96                   | 7.22     | 50.28           | 158.74     |
| Bekasi river water                          | 1.48                   | 7.33     | 41.05           | 135.20     |

Measurements are then made on artificial samples, to find out the value of water quality due to household waste. The artificial waste sample is made from beverage, foods, detergents, and various household wastes mixed with water to resemble the actual household waste. The measurement results for mixture composition of water and artificial pollutants are shown in Table 4. It found that increasing of water mixture composition reduces the magnetic field, turbidity, and TDS parameters, vice versa it will increase the pH value. The highest magnetic field, 11.85 Gauss, is obtained by
sample of 100% artificial waste. The sample also has highest turbidity and TDS value, on the contrary, its pH value is lower than others.

| Sample                          | Magnetic Field (Gauss) | pH (pH)  | Turbidity (NTU) | TDS (ppm) |
|---------------------------------|------------------------|----------|----------------|-----------|
| artificial wastewater 100%      | 11.85                  | 3.60     | 62.35          | 205.31    |
| artificial wastewater 90% + 10% water | 10.37                  | 3.69     | 59.02          | 200.27    |
| artificial wastewater 80% + 20% water | 8.89                   | 3.75     | 54.21          | 197.44    |
| artificial wastewater 70% + 30% water | 7.41                   | 3.80     | 52.54          | 192.14    |
| artificial wastewater 60% + 40% water | 5.93                   | 3.84     | 48.31          | 188.19    |
| artificial wastewater 50% + 50% water | 4.45                   | 3.91     | 45.20          | 182.72    |

### 3.3. Influence of magnetization

The influence of magnetization on pH, turbidity, and TDS was observed by applying a magnetic field of 15 Gauss, 24 Gauss, and 37 Gauss to the sample, in time variation of 5 minutes, 10 minutes, 15 minutes, and 20 minutes. The magnetized solution sample used in pH observation are acidic water, turbid river water, and alkaline water. Meanwhile, the magnetized solution sample used in TDS & turbidity observation is river water contaminated by household wastes.

#### 3.3.1. Influence of Magnetization on pH

The pH value of the solution sample changes when subjected to a magnetic field. The greater of the magnetic field in the sample, the pH value more increases. As a result of the Lorentz force on the ion when the ion moves through the magnetic field, there is a shifting of ion and particle. This shifting disrupts the bond of water ions and molecules, it causes the formation of many hydroxide ions (OH\(^{-}\)). The more hydroxide ions are formed, the pH value will increase.

The measurement results of pH increasing because of magnetization of 37.02 Gauss in time variations of 5 minutes, 10 minutes, 15 minutes, and 20 minutes are shown in table 5. The acid solution has the highest percentage increasing by 1.22% when given magnetization of 37.02 G for 20 minutes. This shows that acidic water is easier to produce hydroxide ions (OH\(^{-}\)) than other solution samples.

#### 3.3.2. Influence of Magnetization on Turbidity and TDS

The effect of magnetization on turbidity and TDS is shown in Figure 2a and 2b. It is seen that the turbidity and TDS values decrease when the sample is magnetized. Because the iron and other particles contained in water will be attracted by the magnetic field, so the turbidity and TDS of the solution decrease. The greater the magnetic field, the clearer the sample.

The turbidity begins to decrease of 0.01 NTU after being magnetized by a magnetic field of 15.79 Gauss for 20 minutes or 24.89 Gauss for 15 minutes. On the other hands a decrease in TDS requires a faster magnetization process, to reduce TDS of 1 ppm needs a minimum magnetic field of 15.79 Gauss for 15 minutes. The maximum TDS reduction is 1.05 %, and the maximum turbidity reduction is 0.19 %, by applying magnetization of 37.02 Gauss in time interval of 20 minutes.
Figure 2. (a) Turbidity value of the sample due to magnetization (b) TDS value of the sample due to magnetization

4. Conclusion

Development of a water quality measurement system, focus on the parameters of turbidity, pH, total dissolved solids and magnetic fields has been carried out successfully. The highest pH increasing by 1.22% was achieved by acidic water by given magnetization of 37.02 Gauss in time interval of 20 minutes. The dissolved substances will be attracted by the magnetic field, thus decrease the amount of substance. The decreasing of TDS value requires a smaller magnetic field than the turbidity value. By applying magnetization of 37.02 Gauss in time interval of 20 minutes, the maximum TDS reduction is 1.05 %, and maximum turbidity reduction is 0.19 %.

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