Measurement system development of refractive index, salinity and magnetic field parameters on liquid waste polluted water

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Abstract. A Prototype of liquid waste polluted water measurement system based on refractive index, salinity, and magnetic field parameters, has been developed. The instrument consists of Potentiometer, Light Dependent Resistor (LDR), conductivity sensor, Hall Effect sensor, and microcontroller. Potentiometer and LDR sensors are used to measure the refractive index, a conductivity sensor as the salinity measurement device, Hall Effect sensor as a magnetic field detector, and Arduino UNO as the control system. Each sensor has been characterized using a standard measuring instrument to determine sensor sensitivity. The characterization results showed that the refractive index sensor has a sensitivity of 321.8 mV/refractive index unit and a relative error of 0.35%. The conductivity sensor has a sensitivity of 415.2 mV/ppt and a relative error of 5.26%. The magnetic field sensor has a sensitivity of 0.0077 Volt/Gauss and a relative error of 4.29%. The prototype was used to measure the water quality of artificial wastewater and river water samples. The artificial wastewater was made of the composite of water, salt, and liquid soap with different concentrations, and the river water samples were taken from ten different regions. The results show that the addition of salt and liquid soap concentration was directly proportional to the refractive index, salinity, and magnetic field. All samples have salinity below the normal threshold of <0.5 ppt.

1. Introduction
Waste is one of the environmental problems that have a high potential to reduce the quality of the environment and health. Liquid waste is one type of waste that is often found in the community. Liquid waste comes from the remaining wastewater of households, industries, public places such as restaurants, offices, and so on. Type and quantity of liquid waste increases, along with population growth and economic development. According to the Ministry of Environment and Forestry in 2017, 68% of river water in Java has been heavily polluted, especially by liquid waste. Due to a large amount of domestic waste directly discharged into the river without the waste treatment process [1]. This condition certainly proves that there is a decrease in water quality which impacts environmental damage and health problems. Therefore, we need an action to overcome the waste's problems, through monitoring and measurement of liquid waste quality, that covers the quality of physics, chemistry, and biology. The physical quality is determined by the parameter of electric conductivity, dissolved solids, thermal conductivity, viscosity, turbidity, etc [2].

Other measurement parameters are refractive index, salinity, and magnetic field. The Refractive index is an important optical property of a medium [3]. It can be used to determine the solution's concentration and composition of the solution ingredients. Changes of the refractive index can indicate
the presence of various mixed materials in a medium [4]. Meanwhile, salinity is the value of the salt concentration of water. Salinity influences the survival of aquatic biota because the magnitude of water salinity influences the osmotic pressure, and each aquatic biota has tolerance to salinity related to osmotic pressure [5]. The magnetic field is an important parameter in the water purification process [6]. It has a high influence on water pH dan total dissolved solids (TDS) [7,8], as well as the physicochemical properties of water [9]. This paper describes the development of measurement systems of liquid waste polluted water with parameters of refractive index, salinity, and magnetic fields.

2. Methods

The developed instrument composes of Potentiometer, LDR sensor, conductivity sensor, Hall Effect sensor, and microcontroller. Potentiometer and LDR sensors are used to measure the refractive index, conductivity sensor as the salinity measurement device, Hall Effect sensor as a magnetic field detector, and microcontroller type of Arduino UNO as the control system. The measurement results will be processed by Arduino UNO and displayed by a 16x4 liquid-crystal display (LCD).

![Flowchart of program](image-url)

Sensor characterization, by using a standard measuring instrument, was carried out to determine the sensitivity, measurement range, and relative error measurement of the sensor [10]. The sensor characterization is divided into three parts, there are refractive index sensor characterization, conductivity sensor characterization, and magnetic field sensor characterization. The characterization of refractive index measurement is by comparing the output voltage of the sample using LDR and potentiometer measurement to the results of refractometer measurements. The potentiometer is used to measure the position shifting of the laser beam due to the sample solution. The used water sample is river water taken from the Bekasi Timur-river, which is added with liquid soap in 10 volume variations. The process of conductivity sensor characterization is by comparing the conductivity sensor output voltage to the SA-287 type salinometer measurement. There are 13 samples measured in this process, each sample consists of 1000ml of river water and mixed with salt in different mass variations, 50mg -
Meanwhile, the Effect Hall sensor was characterized using a calibration coil, a diameter of 5.6 cm, and the number of turns 740, as a source of an artificial magnetic field. The program flow chart is shown in Fig. 1. After the system is built, a measurement of three physical parameters was carried out using artificial samples and polluted river water samples, simultaneously.

3. Results
The following are presented sensors characterization results, and prototype experiment using both artificial samples and polluted river water.

3.1. Characterization of Sensors
The results of LDR sensor characterization, conductivity, and hall effect are shown in Figure 2. From each graph, sensor sensitivity can be determined using equation 1, which is the ratio of the sensor output signal to input signal [2].

\[ S_y = \frac{\Delta_{output}}{\Delta_{input}} \]  

![Figure 2. The characterization of sensors (a) LDR (b) Conductivity (c) Magnetic field.](image)

Figure 2. The characterization of sensors (a) LDR (b) Conductivity (c) Magnetic field.

From Fig. 2 (a), 2 (b) and 2 (c) obtained equation (2), (3), and (4), respectively.

\[ y = -321.8x + 432.75 \]  
\[ y = 415.2x + 66.461 \]  
\[ y = 0.0077x + 0.1001 \]

Based on the three equations above, sensor sensitivity can be determined. LDR sensor has a sensitivity of -321.8 mV/unit of refractive index, conductivity sensor has a sensitivity of 415.2 mV/ppt, and Hall effect sensor has a sensitivity of 0.0077 V/G. LDR sensor has a minus value of sensitivity, indicating that increase in refractive index causes the resistance of sample solution to be higher, so the sensor output voltage decreases. Whereas the output of the conductivity sensor is proportional to the sample-
solution salinity. The increasing salt concentration makes the number of rising moving ions, so the conductivity value is higher. Meanwhile, the Hall effect sensor capable of detecting 1 Gauss input and produces 7.7 mV output voltage. The measurement relative error of refractive index, salinity, and magnetic field by using sensors against laboratory instruments are 0.35%, 5.26%, and 4.29%, respectively.

3.2. Prototype measurement

Prototype measurement is carried out to ensure the ability of instrument proper working simultaneously. The prototype measurement is divided into two parts: (i) uses artificial liquid wastewater samples and (ii) uses polluted river water samples.

3.2.1. Artificial liquid samples. This measurement aims to determine the effect of liquid samples concentration increasing on salinity, refractive index, and magnetic fields. The used sample is variations of liquid soap and salt mixture that dissolved into 1000 ml of water. The results of artificial sample measurements are depicted in table 1.

According to table 1, the highest magnetic field intensity, refractive index, and salinity are achieved in an artificial sample with a salt concentration of 150 mg and liquid soap of 20 ml. Instead, the lowest values are achieved in artificial liquid waste with the lowest concentration. This shows that the results of physical parameters measurement of the sample using a developed prototype are following the theory.

| Salt (mg) | Liquid soap (ml) | Magnetic field (Gauss) | Refractive Index | Salinity (PPT) |
|----------|-----------------|------------------------|-----------------|----------------|
| 50       | 4               | 4.333                  | 1.3333          | 0.281          |
| 8        | 4.572           | 1.3333                 |                 | 0.315          |
| 12       | 4.824           | 1.3340                 |                 | 0.372          |
| 16       | 5.134           | 1.3343                 |                 | 0.396          |
| 20       | 5.273           | 1.3346                 |                 | 0.417          |
| 100      | 4               | 4.435                  | 1.3332          | 0.301          |
| 8        | 4.612           | 1.3335                 |                 | 0.332          |
| 12       | 4.951           | 1.3343                 |                 | 0.386          |
| 16       | 5.296           | 1.3345                 |                 | 0.400          |
| 20       | 5.425           | 1.3350                 |                 | 0.421          |
| 150      | 4               | 4.542                  | 1.3335          | 0.324          |
| 8        | 4.733           | 1.3343                 |                 | 0.343          |
| 12       | 5.141           | 1.3346                 |                 | 0.394          |
| 16       | 5.327           | 1.3350                 |                 | 0.410          |
| 20       | 5.552           | 1.3353                 |                 | 0.432          |

3.2.2. Polluted river water samples. In this measurement, ten water samples taken from different rivers around Bekasi and Jakarta area were used. Each water sample has a volume of 1000 mL. The results of river water sample measurements are depicted in table 2.

Based on the results, it appears that the prototype can work properly in physical parameters detecting of all samples. A river water sample from the Galur region has the highest magnetic field intensity, as well as the refractive index and salinity values. This indicates the poor quality of the water. The lowest
salinity of samples was achieved by river water samples from the Central Kampung area. This is caused by the influence of high evaporation and precipitation.

**Table 2. River water sample measurement**

| Sample of river water | Magnetic field (Gauss) | Refractive Index | Salinity (PPT) |
|-----------------------|------------------------|-----------------|--------------|
| Kampung Tengah         | 4.312                  | 1.3333          | 0.098        |
| Bidara Cina           | 4.420                  | 1.3334          | 0.149        |
| Teluk Pucung          | 4.469                  | 1.3334          | 0.176        |
| Bekasi Timur           | 4.516                  | 1.3334          | 0.181        |
| Cipinang              | 4.971                  | 1.3335          | 0.219        |
| Halim                 | 5.070                  | 1.3335          | 0.221        |
| Rawajati              | 5.121                  | 1.3335          | 0.271        |
| Condet                | 5.134                  | 1.3335          | 0.274        |
| BKT                   | 5.446                  | 1.3345          | 0.378        |
| Galur                 | 7.920                  | 1.3345          | 0.423        |

4. Summary

Development of a liquid waste polluted water measurement systems focus on the parameters of refractive index, salinity, and magnetic fields has been carried out successfully. The prototype can work properly in physical parameters detecting of all samples. All samples have salinity below the normal threshold of <0.5 ppt. A river water sample from the Galur region has the highest magnetic field intensity, as well as the refractive index and salinity values.

Acknowledgments

The authors are thankful to the Faculty of Mathematics and Science, Universitas Negeri Jakarta that has funded this research.

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