Characterization of turbidity water sensor SEN0189 on the changes of total suspended solids in the water

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Abstract. Turbidity has an indication that the liquid has been contaminated. In the testing process, turbidity in water can only be measured by sampling. To be able to maintain the quality of water, required a tool that can monitor and measure the level of turbidity of water in real time. water turbidity sensor SEN0189 is a sensor that works by measuring the amount of light from infrared led into the phototransistor that will produce the output voltage on the sensor. The study was conducted to be able to characterize the ability of sensors in detecting water turbidity. The method used is to test the sensors using sediment soil that has been filtered with a diameter of <60μm to be added into the pond containing 1 liter of water. The results show that the greater the concentration of sediment dissolved in the water pool the sensor output voltage will be smaller. The sensor has a sensitivity of -0.0008 and the output voltage when the sensor detects 0 NTU is 3.9994 volts with 5V operating voltage and the sensor can detect water turbidity linearly within the test range 1.873 NTU to 1011.93 NTU.

1. Introduction

Water is a chemical compound that is a source of human life used to fulfill the needs for everyday activities such as drinking, bathing, washing and other activities [1]. To fulfill the needs of these daily activities, it is required enough clean water to be used. According to the Central Bureau of Statistics (2016), in Indonesia the number of clean water customers managed by the company increased by 3.48% in 2013-2014 and by 2014-2015 increased by 4.26% [2]. These data indicate that the need for clean water increases with the increasing number of human service users of water providers each year in Indonesia [3]. In the process of providing and managing clean water, a raw water source that fulfills the qualified water treatment requirements listed in SNI 6773 in a year 2008 regarding the Specification of the Unit of the Water Treatment Plant Package [4]. Raw water sources are not possible to be processed into a clean water have an impact on the lack of quantity of clean water that can be distributed to the community.

One of the problems that occur in raw water sources is the level of raw water that has been processed raw material cannot be directly distributed for consumption or drink without re-processed by the community as drinking water because the level of turbidity of water is not well informed by the provision of drinking water to the community. This issue of raw water and drinking water is one of the strategic issues expressed by the Working Group on Water Supply and Environmental Sanitation (POKJA AMPL) for Indonesia's efforts to achieve drinking water development targets within the MDG framework by 2015 [5]. Under ISO 7027 in 1999, turbidity is a reduction of fluid transparency caused

by the presence of non-soluble material in the liquid [6]. Turbidity also shows that water has been tainted by mud and other microorganisms that can cause turbidity [7]. Turbidity if it is not acted upon will be problematic because pathogens can live in turbid water [8]. In the process of developing sensors that can detect water turbidity some researchers do research using the concept of optics as the foundation of the research made. A water turbidity sensor is designed by Parra et al. (2018), using LDR and photodiode provided a light source of color LED for LDR and infrared LED for infrared photodiode [9]. And a turbidity meter is designed by Kautsar et al. (2016) using a photodiode that can be displayed using the LCD as a display, this tool is controlled using ATMega328 [10].

In this paper a water turbidity sensor SEN0189 that has become one sensor module tested and has been characterized, this water turbidity sensor used an infrared LED and an infrared phototransistor is placed at 90° from the light source to detect a number of suspended solids in the water. Sediment was used for turbidity samples as one of the materials that turbid water, especially a raw water from a soil. This water turbidity sensor can be developed into an integrated system using a microcontroller to detect turbidity of water in real time.

2. Materials and Methods

2.1. Background

Before water turbidity sensors tested and can be characterized, we need to describe how the sensor works when we try to test that sensor. The block diagram on figure 1 below was designed to describe that SEN0189 used infrared LED for the light source and used infrared phototransistor to detect how much the amount of light not blocked by the turbid water. The infrared phototransistor will have change resistance itself and the change of voltage sensor will be obtained. The data will be processed by a microcontroller using Arduino board and connected to a display on PC. And those data recorded using Microsoft Excel after we process the average of the voltage change data will be taken when the sensor detects the turbidity water after added a number of sediment and stirred the water to distribute the sediment on a water pool.

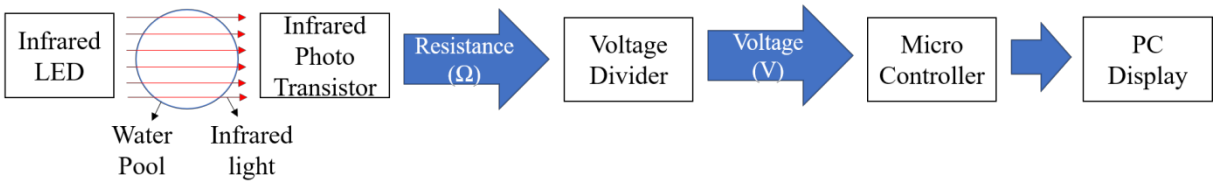

Figure 1. Block Diagram of The Design Sensor Testing.

To characterize a turbidity sensor, we need a turbidity water in the water pool the water will be poured with solids and the used solid was a sediment. When a number of sediment added to water pool it's made a water turbid and it's mean total suspended sediments (mg/l) has relation with the turbidity of water (NTU). The equation (1) below shown in Sendra et al. (2013) [11], and used by Parra et al. (2018) to relate total sediment suspended in the water with the turbidity unit in NTU. That's equation is obtained by measuring the mass of sediments and provide a number of it into a liter of water and the device to measure the turbidity is the Hach 2100N turbidimeter [9].

$$Turbidity\ of\ Water\ (NTU) = (1.873 + (0.518 \times Total\ Suspended\ Solids\ (mg/L))) \quad (1)$$

The above equations will be simulated using the MATLAB application so that the equation has been proofed and can be used as the relationship between water turbidity sensors with total of suspended sediments.

2.2. Turbidity Sample

To characterize the turbidity sensor of the water is done by testing the sensor using water that is poured using the sediment soil that has been filtered using a test filter. The sampling process was carried out at Universitas Pendidikan Indonesia in Instrumentation Physics Laboratory of FPMIPA B building on Thursday, March 29, 2018 by using filter sieve analysis with filter sieve diameter of 45 μm, 60 μm, 250 μm, and the sample obtained has size <60 μm diameter. According to ISO 14688-2: 2004 (en) sand has diameter> 63 μm, silt has diameter 2 μm-63 μm, clay have diameter <2 μm. The turbidity samples obtained shown by the following figure 2 are a mixture of silt and clay from the result of the filtration process. [12].

Figure 2. Turbidity Samples as Sediment with a size of <60 μm diameter.

2.3. Design of the Testing Turbidity Water Sensor

Sensor SEN0189 is a sensor that can measure the turbidity of water (a number of particles suspended in water). This sensor uses an optical transistor and LED to measure the amount of light from the incoming LEDs to the optical transistor when it is used to measure and calculate the turbidity levels in water. The mode of action of this sensor is based on the principle that when light is passed from photodiode to phototransistor in water, the amount of light transmitted through water depends on the amount of other matter suspended in the water [13], if the amount of other material increases then the amount of light transmitted by the photodiode towards the phototransistor will be reduced because it is blocked by other materials [14]. The working principle of this circuit is when the sensor is inserted into the turbid water then the sensor will provide analog data that will grow larger along with increasing turbidity in water. The analog data will be read and converted by microcontroller into an analog signal to be converted to the output voltage of the sensor as a result of the measurement [15].

The testing of turbidity sensor was designed by a figure below was described how the data obtained. The line on figure 3 explain the wiring of microcontroller to the turbidity sensor and the microcontroller connected to the PC to record the data using serial monitor in Arduino IDE. The average data from the serial monitor processed by Microsoft Excel. The average of the voltage change data will be taken when the sensor detects the turbidity water after added a number of sediment and stirred the water to distribute the sediment on a water pool. The sensor detects the change of light transmitted in the water because of the change of the total suspended solids from the addition a number of sediments on it.

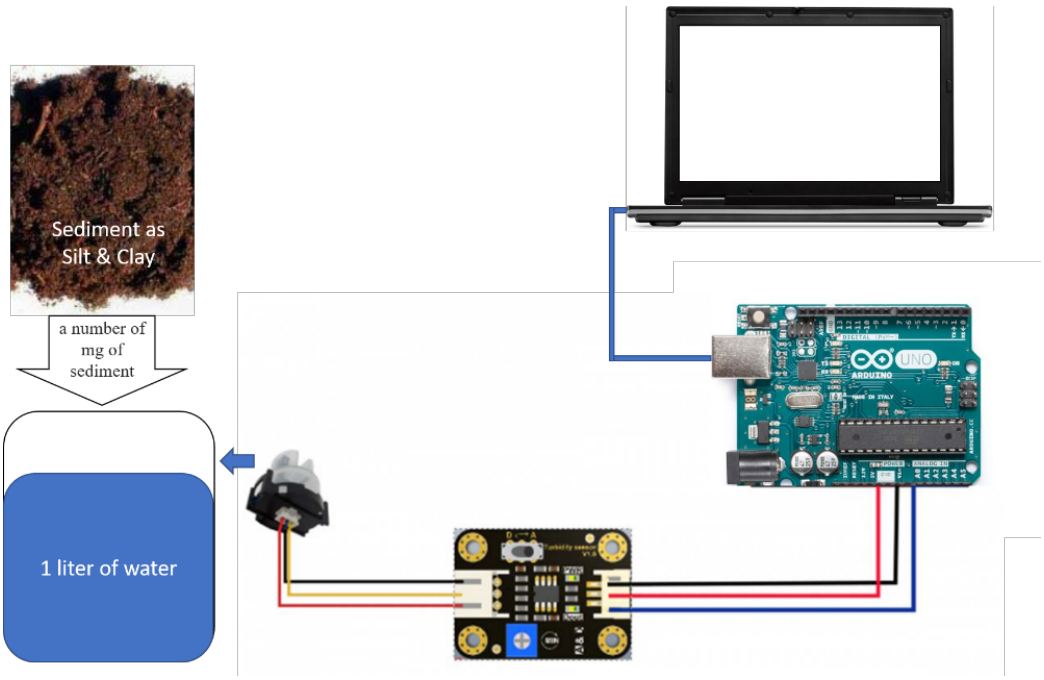

Figure 3. Design of the Testing Turbidity Sensor.

2.4. Research Phases

The method of this research explained in the flow chart on figure 4 as stages of research included a design test scheme. The test scheme of turbidity water sensor was designed by the stages below:

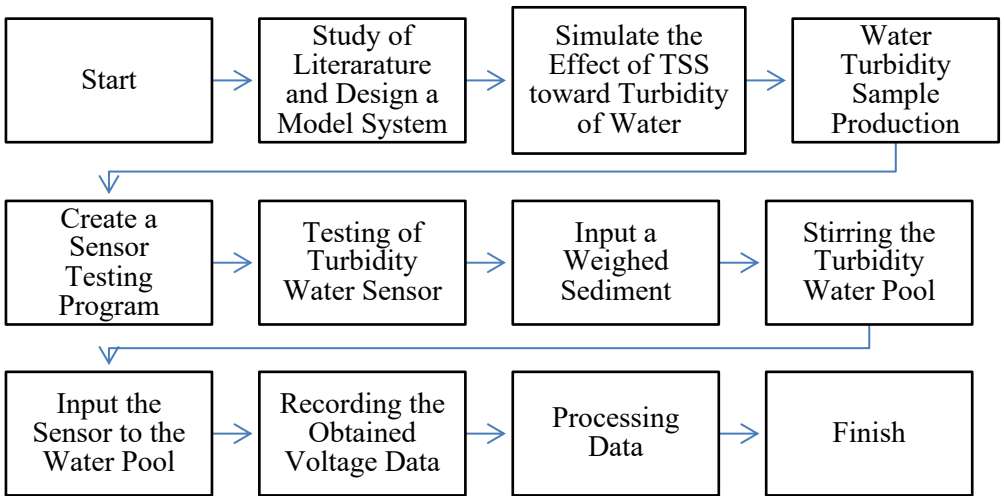

Figure 4. Design of the Research Phases.

The figure 4 above explained the process this research from study of literature and the design a model system. Before the test begin, we need to simulate the effect of the total suspended solids with the turbidity unit. After the simulation is done, we begin the production of water turbidity and creating a sensor testing program. The testing methods is input a sediment that has been weighed to a place filled with a water and the water will be stirred to distributed the sediment. The sensor will be inputted to water pool and the voltage output data will recorded from the serial monitor on Arduino IDE. The following data will be processed using Microsoft Excel and the result will be analyzed in this paper.

3. Result and Discussion

3.1. Relation Between Total Suspended Sediment with Turbidity of Water

Before we test turbidity SEN0189, we need to prove the equation that have been used by previous researcher. In order to prove the equation, we need to model the number of suspended sediment in the water. The model was designed using program in the form of source code to process data from simulation process, which is done by using MATLAB R2014a and by using "cftool" function in command window on MATLAB to receive the result. The equation (1) above can be proved by polynomial fitting with 1 degree or it can be called by linear equation.

The plotting graph shown by the following figure 5 below and the result of polynomial 1 is same meaning as the fitting linear. The equation from figure 5 can be written as the equation (2) below:

$$f(x) = ((0.518 \times x) + 1.873) \quad (2)$$

the f(x) variable means turbidity of water in NTU and x variable means total suspended sediment in the water.

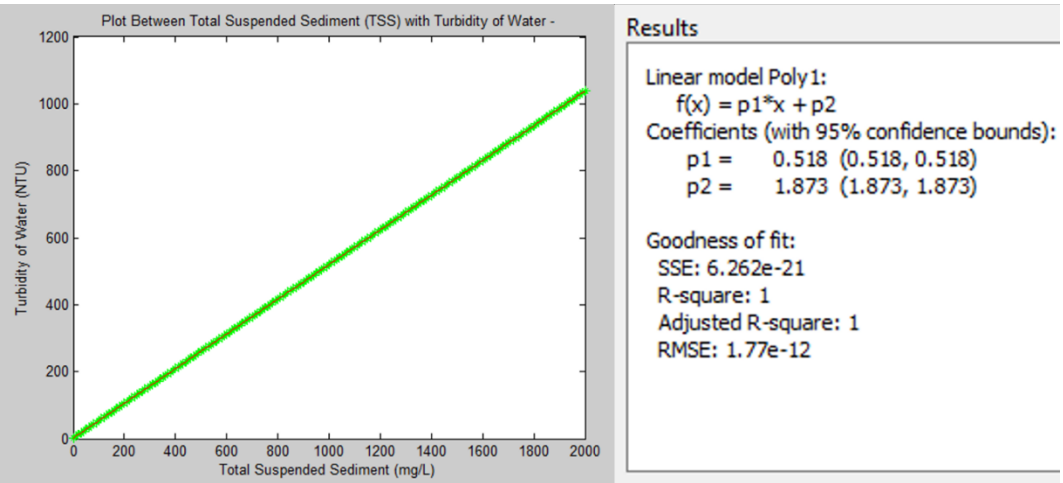

Figure 5. Result of Simulation between Total Suspended Sediment with Turbidity of Water.

From the equation (2), we can see that the equation (1) before was right to relate total suspended sediment in the water affects turbidity of water linearly. The simulation shown the good result and the following equation can be used to describe a relation between total suspended sediment in the water with the turbidity on it.

3.2. Water Turbidity Sensor Test

After performing the data retrieval process to know the sensor characteristics and sensor capability to detect the turbidity level, obtained large data of sensor output voltage to change of turbidity level of water obtained by adding sediment to a number of water. A quantity of raw water is simulated using 1-liter potable water mixed with sediment as a suspended substance in the water. The range of measuring instruments is from 0 until ±1000 NTU and examined from the water level of turbidity that can be drunk up to standard raw water source of 600 NTU. This is done so that this tool can monitor the turbidity of water in raw water treatment process.

The study was conducted at the author's residence on Thursday, April 4, 2018 at the time of the study, the room thermometer showed a temperature of 25° C. by using drinking water as much as 1-liter and the mass of sediment which weighed using the mg scale will be obtained data of sediment concentration that exist in that water. And the data obtained in the study are as follows:

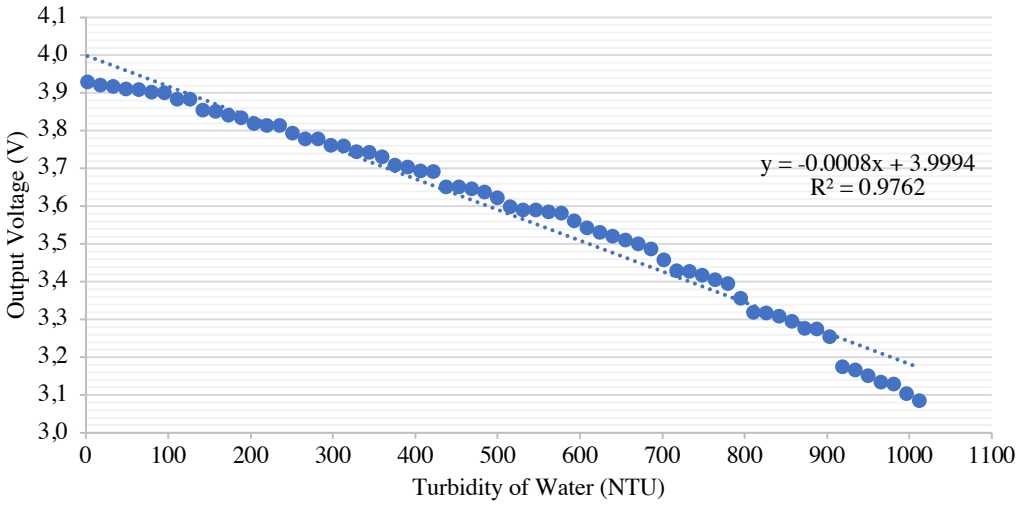

Figure 6. Graph of The Output Voltage to Turbidity of Water.

The graph above on figure 6 shows the plot of the effect of the sensor output voltage which is affected by the turbidity level of the water, from the graph above we can see from the range of turbidity 0 NTU to 900 NTU is quite linear. If we fit the data using the linear fit, we can get the equation that describe the characteristics of the turbidity sensor. the equation (4) below obtained from fitting the data using the equation of straight-line (3). The equation represents y variables which is describes the number of output voltages that will be generated when changes are detected at variable x which is the water turbidity level. the results of the equations obtained through the sensory test are as follows:

$$y = mx + c \tag{3}$$

$$\textit{Output Voltage (V)= -0.0008× (Turbidity of Water (NTU)) + 3.9994} \tag{4}$$

The gradient m = -0.0008 on equation (4) shows sensor sensitivity or sensor speed in acquiring water turbidity data converted to output voltage, minus sign at gradient indicates output voltage will decrease every increase of turbidity of water, and constant $c = 3.994$ is y_o or constant of initial output voltage which shows the output voltage when the sensor detects water with a turbidity level of 0 NTU or when the water is not turbid at all.

4. Conclusions

In this paper, we design to characterize water turbidity sensor to known the ability of that's sensor. The relation between total suspended solids and turbidity of water worked by the simulation using MATLAB R2014, and the simulation shown the good result and from the following equation (2), we can see that the equation (1) before was right to relate total suspended sediment in the water affects turbidity of water linearly. The equation (1) before can be used to describe a relation between total suspended sediment in the water with the turbidity on it.

The ability of water turbidity sensor in detecting water turbidity level from the changes of the turbidity of water can be shown through the equation (4) that obtained from the results of research that has been done. The variable y shows the output voltage of the turbidity sensor of water and the variable x shows the turbidity value of water and the value of 3.9994 is the constant y_o that is the sensor output voltage value at the turbidity of 0 NTU. The gradient m = -0.0008 on graph shows sensor sensitivity or sensor speed in acquiring water turbidity data converted to output voltage, minus sign at gradient indicates output voltage will decrease every increase of turbidity of water. This sensor has a range of measuring turbidity of water from 0 until ±1000 NTU and can be used to measuring a maximum of turbidity of raw water which has 600 NTU. From the equation (4) we can develop the tool using a real

time system and can be communicated using a wireless communication based on Decision-Tree-Based Multi-Hop Routing System using Dijkstra algorithm to be able to save energy used by the sensor to communicated [16].

5. References

[1] Susana T 2003 Air Sebagai Sumber Kehidupan *Jakarta:Pusat Penelitian Oseanografi-LIPI* **28** 17–25
[2] BPS 2016 *Jumlah Pelanggan Perusahaan Air Bersih* https://www.bps.go.id
[3] UNICEF 2012 *Air Bersih, Sanitasi & Kebersihan* https://www.unicef.org
[4] S. Nasional, I. Ics, and B. S. Nasional 2008 *Spesifikasi Unit Paket Instalasi Pengolahan Air*
[5] POKJA AMPL 2004 *Isu-Isu Strategis & Permasalahan* http://www.ampl.or.id
[6] ISO 1999 *Water Quality - Determination of Turbidity 7027* https://www.iso.org
[7] Awaludin F F 2015 *Permasalahan Pencemaran dan Penyediaan Air Bersih di Perkotaan dan Pedesaan* https://www.researchgate.net/
[8] Lambrou T P, Anastasiou C C and Panayiotou C G 2009 A nephelometric turbidity system for monitoring residential drinking water quality In *International Conference on Sensor Applications, Experimentation and Logistics* 43-55
[9] Parra L, Rocher J, Escrivá J and Lloret J 2018 Design and development of low cost smart turbidity sensor for water quality monitoring in fish farms *Aquacultural Engineering* **81** 10-18
[10] Kautsar M, Isnanto R R and Widianto E.D 2015 Sistem Monitoring Digital Penggunaan dan Kualitas Kekeruhan Air PDAM Berbasis Mikrokontroler ATMega328 Menggunakan Sensor Aliran Air dan Sensor Fotodiode *Jurnal Teknologi dan Sistem Komputer* **3** 1 79-86
[11] Sendra S, Parra L, Lloret J and Jiménez J M 2015 Oceanographic multisensor buoy based on low cost sensors for Posidonia meadows monitoring in Mediterranean Sea *Journal of Sensors*
[12] ISO 2004 *Geotechnical investigation and testing - Identification and classification of soil* https://www.iso.org/
[13] Amphenol Advanced Sensors 2018 *TSW-10 Turbidity Sensor* https://www.mouser.com/
[14] Daigavane V V and Gaikwad M A 2012 Water Quality Monitoring System Based on IOT *Advances in Wireless and Mobile Communications. ISSN* **10** 5 1107–1116
[15] DFrobot 2017 *Turbidity sensor SKU: SEN0189* https://www.dfrobot.com/
[16] Hasanah L, Aminudin A and Yuwono H et al. 2018 Multi-Hop Wireless Sensor Network Performance and Energy *Pertanikan Journal Science & Technology* **26** 1 427-440