Microcontroller Based Water Measurement Level Prototype Using Fuzzy Logic Method

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***Abstract* – Water is the source of life for humans. Its sustainability has to be maintained because water's quality will affect human life. One of the water sources that are usually used by people is from the local water Company (PDAM) in every city in Indonesia. One of the PDAM Companies in the Marabahan City, South Kalimantan, is treating water from the Jejangkit River, but that water is not always clean; it can be murkier in a rainy season and tidal conditions. That is why the water quality condition in that river needs to be known. In that case, this study aims at designing a prototype of microcontroller-based turbidity of water detector by implementing the fuzzy logic. It can send a real-time report where later it will be used by PDAM in Marabahan City. The stages of turbidity measurement consist of start, initialization of I/O, turbidity sensor of reading object, fuzzy logic, read the turbidity level, stop. The result of this study is that the developed prototype is able to read the turbidity level of water and it can send a real-time report. It is recommended to develop the further turbidity sensor by using other components that are not only able to read the turbidity level, but they are also able to read the pH value and can be developed with other methods, in order that it can read the sharper data accuracy.**

***Keywords* –Turbidity, Turbidity Sensor, Fuzzy.**

DOI: 10.18421/TEM92-36
https://doi.org/10.18421/TEM92-36

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Received: 28 March 2020.
Revised: 20 April 2020.
Accepted: 25 May 2020.
Published: 27 May 2020.

1. Introduction

Water (H_2O) is the most valuable resource and abundant compound on the surface of the Earth, covering more than 70% of the planet [1]. Although the earth consists of 70% water, only 2.5% is freshwater that can be consumed, which makes freshwater a valuable thing that has to be maintained and monitored for its quality [2]. Moreover, if there is an increase in population, there will be an increase in the need for clean water [3]. Water quality from rivers has considerable importance on the grounds that these water resources are generally used as producers of wastewater such as: drinking in agriculture and housing in agricultural areas, agriculture (irrigation), hydroelectric power, transportation and infrastructure, tourism, recreation, and other water sources that are humanely damaged [4]. As we know, turbid water is one of the characteristics of unhealthy water or can be an indication that the water has been contaminated [5]. Meanwhile, clean water is a type of water quality that is of good quality, and it can be used by humans for daily life [6]. Conversely turbid water if used as drinking water will trigger digestive diseases even those that are acute [7]. The effect of consuming drinking water that is not of good quality, it will have an awfully bad impact on children who are under five years old [8]. So, knowing the water quality is one of the important things to maintain health.

Based on Government Regulation of the Republic of Indonesia number 20 from 1990, water classification according to its designation can be divided into several classes, namely: a) Class I: Water that can be used as drinking water directly without prior treatment; b) Class II: Water that can be used as raw water for drinking water; c) Class III: Water that can be used for fisheries and animal husbandry purposes; d) Class IV: Water that can be used for agricultural purposes and for urban businesses, industry, and hydroelectric power [9].

According to information from the Indonesian Ministry of Health, drinking water that is good for consumption is drinking water that has the following conditions: no taste, no smell, no color and does not contain heavy metals. Water obtained from natural sources consumed by humans carries the risk that it has been contaminated by bacteria (e.g. Escherichia coli) or other harmful substances [10]. The purpose of making these limits is to prevent the occurrence and spread of water-borne diseases. In Indonesia, the drinking water standard that was applied was made in 1975, but it was later improved in 1990 [11]. The importance of water is particularly important, but more important is the concept of clean water. It is estimated that every person on Earth needs 20 to 50 liters of safe clean water every day. This clean water is used for drinking, cooking, simple hygiene, etc., [12]. The provision of clean water for all Indonesians is one of the objectives of the government which is still constrained by limited water supply and existing infrastructure [13]. Clean water is needed by the community, especially in urban areas that use PDAM (Regional Water Supply Company) facilities. No exception in the city area of Marabahan, South Kalimantan, in which clean water needs are also supplied from the PDAM.

Turbidity is one of the parameters in determining water quality. Turbidity is caused by organic matter and inorganic particles suspended in water [14]. Turbidity has a close relationship with the levels of suspended substances in the water. Suspended substances present in water consist of various substances, such as fine sand, clay, and natural mud which are inorganic materials or can also be in the form of organic materials floating in water [15]. The turbidity level of the water can be measured by a measuring instrument called a Turbidimeter, or by comparing the turbidity level of water with or waters with clean water [16]. One of the Subdistricts located in the City of Marabahan, precisely in the Jejangkit District also uses PDAM. The water source used in the PDAM is taking water from the river. The river water in the Jejangkit District area is not always clean, tidal river water is one of the causes of turbidity. Not only that, when the rain falls relatively long and heavy, the water in the river will also become turbid. Sometimes this is the problem for PDAM Officers to check the level of turbidity of the water after it rains. However, the officer is not always on time in checking because there is something busy and other things. The manual system like that will make the results of his work inefficient. Officers have to go back and forth to check the level of turbidity of the water.

The use of electronic circuits in detecting turbidity of water for non-flowing water has been carried out by several previous researchers using different sensors and microcontroller systems [11]. In this study the design of water turbidity detection devices is designed to be used to notify operators in providing treatment for the turbid water [17]. Therefore, it is proposed a prototype to detect water turbidity levels by implementing a microcontroller-based Fuzzy logic method. Fuzzy Logic is a branch of Artificial Intelligence, which is knowledge that makes computers able to imitate human intelligence [18]. Fuzzy logic can solve problems in stored controllers and information processing that can be implemented on embedded systems on microcontrollers [19]. This prototype can detect water turbidity by sending reports in real-time and displaying turbidity data in the form of numbers on the LCD. The definition of real-time here is that when the prototype starts working, the data obtained is immediately sent and displayed on the LCD. With the existing automation in this prototype it is expected to help the performance of the PDAM Officers in Jejangkit District.

2. Theoretical Basis

There are some theories that will be discussed. Those are water, microcontroller, Arduino IDE, Turbidity Sensor, LCD, and Fuzzy logic.

Water is the life foundation and livelihood, and it also becomes a key for sustainability development. The successful water management will have a function as foundation to reach many achievements from 17 aims of sustainable development (SDGs), and also for SDG 6 – it is to "ensure the availability of water and sustainable water management and sanitation for all".

Arduino microcontroller is a platform of physical computing that is open source. What is meant by a platform of physical computing is a system or physical device that uses interactive software and hardware that can receive stimuli from the environment and respond back [20]. The advantages of Arduino microcontrollers are that this device can make programming and debugging easy, it does not require additional programmers who will spend additional costs, and its functions are easy to understand [21]. In addition, several studies have proven that the use of Arduino microcontrollers can produce tools that are able to work effectively and efficiently. As research conducted by [22], which can produce hybrid power generation systems consisting of solar panels, battery packs, fuel cells and direct current and effective and efficient alternating current loads using an Arduino microcontroller.

Arduino IDE is the most open-source software used to write and compile code into the Arduino Module. This is official Arduino software, which makes compiling code easier so that even ordinary people without prior technical knowledge can make them like it, and they have no trouble with the learning process. This system is easy to find for several operating systems such as MAC, Windows, Linux, which runs on the Java Platform which is equipped with built-in functions and commands that play a vital role in debugging, editing, and compiling code in the environment [23].

Turbidity is related to the level of turbidity or water clarity which is the main indicator in determining water quality [24]. Thus, the turbidity sensor is a device used as a standard test tool to determine the level of turbidity of water [25]. Turbidity is an internationally recognized criterion for assessing the quality of drinking water because colloidal particles in turbid water can contain pathogens, chemically reduce oxidizing disinfectants, and hinder efforts to disinfect water with ultraviolet radiation [26].

The Liquid Crystal Display or LCD is a display technology that uses isotropic properties of organic material in the form of liquid-crystal due to the influence of an electric field. Each pixel of an LCD consists of a liquid-crystal layer flanked by 2 transparent electrodes (transparent electrodes) made of Indium Tin Oxide (ITO) and 2 polarizing filters (polarizing filter) [27].

Fuzzy logic is a way to map an object into an output space. Fuzzy Logic was first introduced by Prof. Lotfi A. Zadeh in 1965. The basis of Fuzzy logic is the theory of the set of Fuzzy [28]. Fuzzy logic has been proven to be able to solve problems of measuring water quality, especially when dealing with the uncertainty of data and ambiguity in river water systems [29]. The results of research conducted by [30] states that the Fuzzy logic method is a feasible method to be used in determining water quality. Measurement of water turbidity using the fuzzy logic method was also carried out by several other researchers. A research conducted by [31] which uses fuzzy logic methods for measuring water quality in water treatment plants, where their research shows that water quality measurements using measurement tools based on fuzzy logic method are effective for determining water quality in installations water treatment. Even the Fuzzy logic method is also successful in solving complex problems in other fields. Meanwhile, research conducted by [32] which uses the Fuzzy logic method to map the suitability of nesting habitats for grouse in western Wyoming. The fuzzy logic method is also used by [33] to measure human perception using a questionnaire whose measurements are calculated using the fuzzy logic method.

3. Methodology

The material used in this study based on the results of surveys and on-site observations is river water resources. The tools used to implement this research are Microcontroller and PC (Personal Computer). In this research, the tools used are hardware and software, among others: Computer / laptop with minimum specification of Windows 7, 2GB RAM; Internet connection; Microcontroller; Turbidity sensor; LCD; I2C Module; Jumper Cable. Meanwhile, software that is used on this research is the Arduino IDE.

The plot of the system comprising a flowchart in the measurement of water turbidity level based on a microcontroller using a fuzzy logic method with the data generator is named turbidity sensor as it is shown in Figure 1 below:

Figure 1. The Stages of Research

Some of hardware components used in this research are shown on Table 1 below.

Table 1. Hardware Device

No	Component	Number
1	Microcontroller (Wemos D1)	1
2	Breadboard	1
3	Battery box A4 9V	1
4	Jumper cable	10
5	Turbidity sensor	1
6	Phototransistor	1
7	9V Battery connector	1

4. Results and Discussion

4.1. Prototype Design

In this section, we will explain the stages of prototype design of water turbidity levels using a turbidity sensor connected to the microcontroller, whose tool consists of turbidity sensor, Wemos D1 microcontroller, and LCD, and later this tool will detect water turbidity. The turbidity sensor used is the GE Turbidity sensor. This sensor can read the value of turbidity by using light for entering the water and detecting suspended turbidity particles. The shape of the turbidity sensor can be seen in Figure 2 below:

Figure 2. GE turbidity sensor

This sensor can work by dipping it into the water sample. The output value is in the form of analog data. GE Turbidity Sensor has 4 pins, but the pins are used only 3. Those are the VCC, GND Pin, and A0 Pin. The VCC pin is for positive electric voltage. The function is to turn on the sensor. Meanwhile, the GND pin is for the ground, and the A0 pin is for the input value.

Next, the writer uses the Wemos D1 type microcontroller because it has been inserted by module or wifi chip without need to add the Ethernet Shield as the added tool which is usually used to deliver the circle data. So, this microcontroller usage is simpler, and it has a lower cost as well. The Wemos D1 Microcontroller used can be seen in Figure 3 below:

Figure 3. Wemos D1 microcontroller

The turbidity gauge is then assembled on the Wemos D1 microcontroller by using a jumper cable. Same with the explanation above, to connect Turbidity sensor and microcontroller requires 3 jumper cables. The cable will be connected to the three pins in the microcontroller, namely, the VCC pin on the Turbidity sensor to pin 5v on the microcontroller, the GND pin for the GND pin which is the Turbidity sensor and pin A0 for pin A0 on the Turbidity sensor.

Furthermore, there is an LCD (Liquid Crystal Display), which is one type of electronic display that works by reflecting light that transmits light from back-lit. Here I use a 16x2 LCD which means it has 16 characters and 2 lines. We use the LCD as a tool for viewing turbidity values that are sent from the “Wemos D1 microcontroller”. The shape of the LCD can be seen in the Figure below:

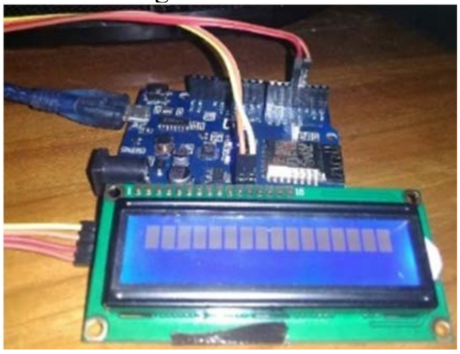

Figure 4. LCD (liquid crystal display)

LCD still has another component that can accept the data. This component is the “Inter-Integrated Circuit” or it is usually called the I2C Module. I2C module is a tool that can send or accept the data. I2C itself has a different address in each part of it. The system of I2C consists of the SDA (Serial Data) and SCL (Serial Clock). The shape of I2C can be seen in the figure below:

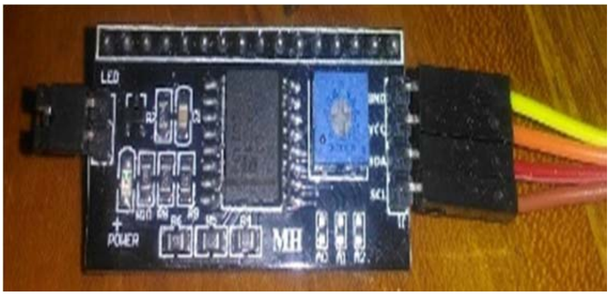

Figure 5. I2C module

I2C is assembled on the LCD by inserting 16 pins in I2C and LCD, this pin transfers the character shape to the LCD. In addition, there are also 4 pins connected to the microcontroller, namely the GND pin for Ground which is also connected to the microcontroller GND pin, the VCC pin for the electric current-voltage connected to the 5V microcontroller pin, SDA and SCL pins which are also connected to the SDA pin and SCL Microcontroller. After everything is assembled it will produce a prototype of water turbidity detection, the results of which can be seen in the following figure:

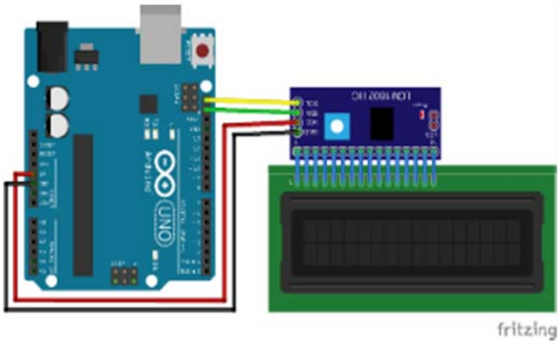

Figure 6. The LCD circuit in microcontroller

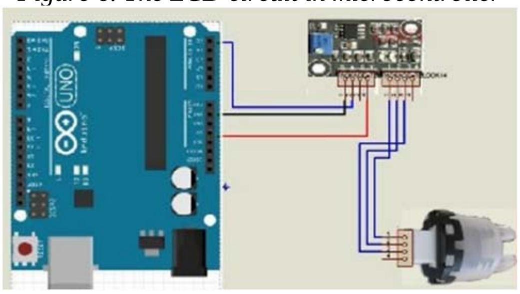

Figure 7. The Turbidity sensor circuit in Microcontroller

4.2. Testing the Result

The rule that is used in this water turbidity research is by implementing the Mamdani fuzzy method is as follows:

- If (NTU is <50) then (Water_Quality is clear)
- If (NTU is >50) then (Water_Quality is intermediate)
- If (NTU is >200) then (Water_Quality is murky)

Before entering the prototype test, manual testing is done by comparing with aquades water that has been labeled NTU value or which can be called the formazin polymer, which can be seen in the picture below:

Figure 8. Formazin polimer liquid

To test the accuracy of the sensor for water turbidity, the author uses 3 water samples in a container where the water has a different turbidity level value. The display of 3 water samples can be seen in the Figure below:

Figure 9. Water sample

After doing the water turbidity level test, the result can be seen in the Table 2, 3, and 4 as follows:

Table 2. Number 1 Water Sample Test

Water Sample of-	Time	ADC Value	NTU Value
1	09:24:32	793	428,32
	09:24:33	781	471,33
	09:24:34	787	449,82
	09:24:35	785	456,99
	09:24:36	788	446,24
	09:24:37	794	424,73
	09:24:38	785	456,99
Average			447,77
Relative error			0,99%

Table 3. Number 2 water sample test

Water Sample number-	Time	ADC Value	NTU Value
2	09:32:14	748	589,61
	09:32:15	745	600,36
	09:32:16	747	593,19
	09:32:17	747	593,19
	09:32:18	747	593,19
	09:32:19	747	593,19
	09:32:20	745	600,36
Average			594,72
Relative Error			0,98%

Table 4. Number 3 water sample test

Water sample number-	Time	ADC Value	NTU Value
3	09:53:22	679	836,92
	09:53:23	687	808,24
	09:53:24	683	822,58
	09:53:25	677	844,09
	09:53:26	685	815,41
	09:53:27	686	811,83
	09:53:28	686	811,83
Average			821,55
Relative Error			0,99%

The formula used for this system result is shown as follows:

$$\frac{TP}{TP + FN}\ x\ 100\%$$

Information:

- TP *(true positive)* = It is also called the hit rate where it shows the right measurement.
- FN *(false negative)* = Un-classified amount.

From the explanation above this research succeeded in making a turbidity sensor by utilizing an Arduino microcontroller and fuzzy logic method to measure water quality automatically. When seen in the current development, namely the 4.0 revolution era, automation becomes a necessity in the business [34]. Similar research, namely the manufacture of Arduino uno-based water turbidity gauges has also been carried out by [1], the results of which also show that the developed tool is able to function properly to measure the level of turbidity of water. Research on turbidity sensors was also carried out by [32]. The difference in their research was that they used optical fiber combined with the use of mirrors. The results of their research show that the measuring devices they make are capable of detecting pollutants that pollute water even in small sizes. In addition, research on turbidity sensors using optical fibers has also been conducted by [28]. The results of these studies indicate that the use of optical fibers is capable of measuring water turbidity online.

Along with the development of the era of turbidity sensor research continues to be carried out to find systems with lower costs and data can be sent online via wireless networks. For example, research conducted by [35], conducted research to develop a low-cost drinking water quality measurement tool for household use. Another example is research conducted by [36], who have succeeded in designing low-cost freshwater turbidity sensors using wireless protocols that are associated with the concept of "internet of things", namely machines communicating with machines. Likewise, with the development of online turbidity sensors is developed by [16] who succeeded in producing web-based sensors at a low cost with the concept of the internet of things. In addition, [10] have also developed a water quality measuring sensor by using the internet of things. They have succeeded in creating a water quality measuring sensor that can automatically warn water quality supervisors in real-time.

Similar water quality measurement sensors were also developed by [5]. The Wireless Sensor Network they developed consisted of a microcontroller to process the system, a communication system for inter and intra node communication, and several sensors. The sensors they have developed have also been reported to be able to commemorate water quality measurement officers via SMS when water quality deteriorates. Similar research that utilizes the GSM system in a turbidity sensor that can report the results of analysis via SMS has also been developed by [31]. The sensor system that they make can report turbidity, pH, and water temperature through short messages so as to reduce operational costs, labor, and speed up the measurement process. Even earlier, in 2013 a tool to measure water quality with a computer system was also carried out by [37]. They developed a water quality measuring device automatically using VB.net and SQL called Surface Water Quality Assessment Tool (SWQAT). Their research succeeded in developing automatic measuring devices which were then installed in several rivers in India.

Although various water quality measurement systems have been created, there are still some obstacles in the measurement system. The obstacle currently faced in measuring water quality is the lack of research conducted in terms of the effect caused by the combination of contaminants in drinking water, especially in drinking water exposed to small amounts of contaminants [23]. In addition, according to [22] in measuring water quality, it is necessary to carry out multi-parameter measurements to get more valid results. Besides that internationally recognized quality standards have to be established. Thus, research on turbidity sensors still needs to be carried out in order to find a system that is more accurate, simpler, and of course lower in cost.

5. Conclusion

Based on the research done, it can be concluded that the Prototype of Microcontroller Based Water Measurement Level using the Fuzzy Logic has been designed successfully. That is why the prototype made by this research is ready to test on a bigger scale, and later it can be implemented in some regional water companies that need the tool to measure the water quality based on the specification and excellence offered from this research. However, the development of this water turbidity level needs to be done in the form of further research so that the measurement is not only limited to the turbidity level, but also on the other things related to the water quality such as Ph and water temperature. So, it can give the water quality data in a more accurate way. Besides that, a system that can be made at a more affordable cost has to be also considered so that it can be used in a wider scope comprising the water quality measurement in the household environment.

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