ONLINE HYDRAULIC PARAMETER MONITORING SYSTEM IN WATER DISTRIBUTION NETWORK

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ABSTRACT. *Water is the source of life. Therefore, in line with the development of monitoring technology and the Internet network, this study aims to create a parameter monitoring system such as pressure, flow and pH on a website-based water distribution network. Besides that, a monitoring system will also be made on the amount of water usage and billing at all times and water quality based on the turbidity level that can be installed on the customer side. This research uses an Arduino microcontroller as controller, pressure sensor, pH sensor, turbidity sensor and water flow sensor, as well as Global System Mobile/General Packet Radio Service (GSM/GPRS) module to send data to the website, and 433 MHz radio for wireless data transmission. In addition, SD cards are used to store data. Based on the results of tests conducted that the monitoring system of pressure monitor, pH and water discharge can work well with a relatively small average error of 0-9.36%. Likewise, the monitoring system of the amount of use and the quality of water using radio networks can also work well with an average error of 1.42-2.06%. Besides that the process of sending data through both the Internet and wireless networks in real time takes place smoothly. However, sometimes data delays occurred due to the density of Internet networks at that time.*
Keywords: Monitoring, Website, Wireless networks, Sensor, Water pressure, pH, Water flow, Turbidity

1. **Introduction.** Water is the source of life for every living thing. Especially for humans, water is used for daily needs, such as for drinking, and bathing. Therefore, its availability must be considered to ensure the sustainability of human life. The Government of Indonesia, through the Regional Water Works Company (PDAM) that is tasked with managing and meeting the citizens' water needs, must guarantee the availability of water supplies that must meet pressure, continuity, and quality requirements. Some problems that appeared are the deficiency of water supply and inadequate water quality. Therefore, water management should be arranged properly and efficiently. The technology in monitoring system has been developed and implemented since Internet network for data communication had been discovered: like, the research in a real-time water distribution network monitoring based on the Internet network [1], the research in urban water distribution network using wireless-sensor [2], the research in water quality (pH, oxygen level, chlorine level, ammonia-nitrogen level monitoring) [3,4], and the research in the advantages and enhancement in efficiency obtained by using online water distribution monitoring [5]; this research is also intended to continue previous researches pressure measurement monitoring based website [6]. Review of water quality monitoring technology with the latest techniques, and recommendations can be made [7]. There is research on monitoring water usage by consumers in real-time with automated smart water meters

[8], and research on the combination of smart water quality and smart water meters [9,10], and the development of water quality monitoring, research with wireless sensor networks and the Internet of Things for more complex and extensive water distribution networks [11,12].

Hence, concomitant with the development of technology in online monitoring, the researcher is interested to develop and implement a Hydraulic Parameter Monitoring System in Water Distribution Network, which can monitor pH, water pressure, water flow in real time and can be accessed online and water usage monitoring system as well as bills and turbidity that can be monitored in every home through radio networks. In this case, the research is held in laboratory scale. There are two prototypes that would be built. The first prototype is concerned in pH, water pressure, and water debit monitoring in PDAM main pipe and can be accessed by the website. On the other hand, the second prototype is developed for monitoring the amount of water debt, payment amount, and water quality consumed by the customer. So that customers can monitor the amount of water used at any time. These two systems are expected to provide an real-time water distribution parameter monitoring database.

2. Proposed Research Methods.

2.1. Overview.
This monitoring system for water distribution networks is made to make it easier and more efficient in obtaining data on the results of measuring the pressure, flow, and pH of water in the pipe. This system consists of making the first prototype that will be placed next to the manager installed on the main pipe of the Regional Watework Company water distribution network system consisting of hardware design which includes solar cell circuits, microcontrollers and input/output circuits and website software design. Besides that, a second prototype was made which will be placed on the customer side which aims to facilitate the data on water discharge used, the amount of payment bills, and the turbidity value of water diagram in Figure 1.

To objectify the system, this research is divided into two parts which are hardware design and software design.

2.2. Hardware design.

2.2.1. *Prototype 1.* Hardware designing of the system is divided into two parts, which are the microcontroller circuit and input/output circuit. To build the microcontroller circuit, an Arduino UNO board with AVR ATMega 328 which has PWM facility, serial communication, ADC, timer, interrupt, SPI, and I2C, is used. Input circuit consisted of pressure sensor MPX5700, a water flow sensor, and a pH meter sensor. The MPX5700AP sensor has an ability to sense water pressure in a range of 0-700 kPa or 0-101.5 psi, and its analog output voltage is in a range of 0.8-4.7 Vdc. The output voltage is linear to the sensed pressure. 1/2 SKU water flow sensor produces a pulse at a level of 2.25 ml and it only needs 1 signal (SIG), 5 Vdc and ground. This sensor is assembled with microcontroller by connecting one of its terminals to pin 1 of Arduino UNO (digital 1); however, terminal pin 2 is connected to ground and terminal pin 3 is connected to VCC. The output of the sensor is digital data. pH sensor is assembled with microcontroller by connecting one of the sensor terminals which is pin 1 to Arduino UNO A1 (Analog port 1); meanwhile, terminal pin 2 is connected to ground and terminal pin 3 is connected to VCC. The output of the pH sensor is an analog data. LCD and GSM/GPRS module are used as a part of the output circuit. LCD (Liquid Crystal Display) is functioned to display the value of water pressure, water flow, and pH, meanwhile GPRS/GSM is functioned to send the data to the server. A photovoltage of 24 WP, 5 A of maximum current, and dry cell battery of 12 V are used as a storage to store the energy, so the system is still

available when there is no energy supply from sunlight as it is in the night time. All parts of this device are assembled and connected to one another as shown in Figure 2.
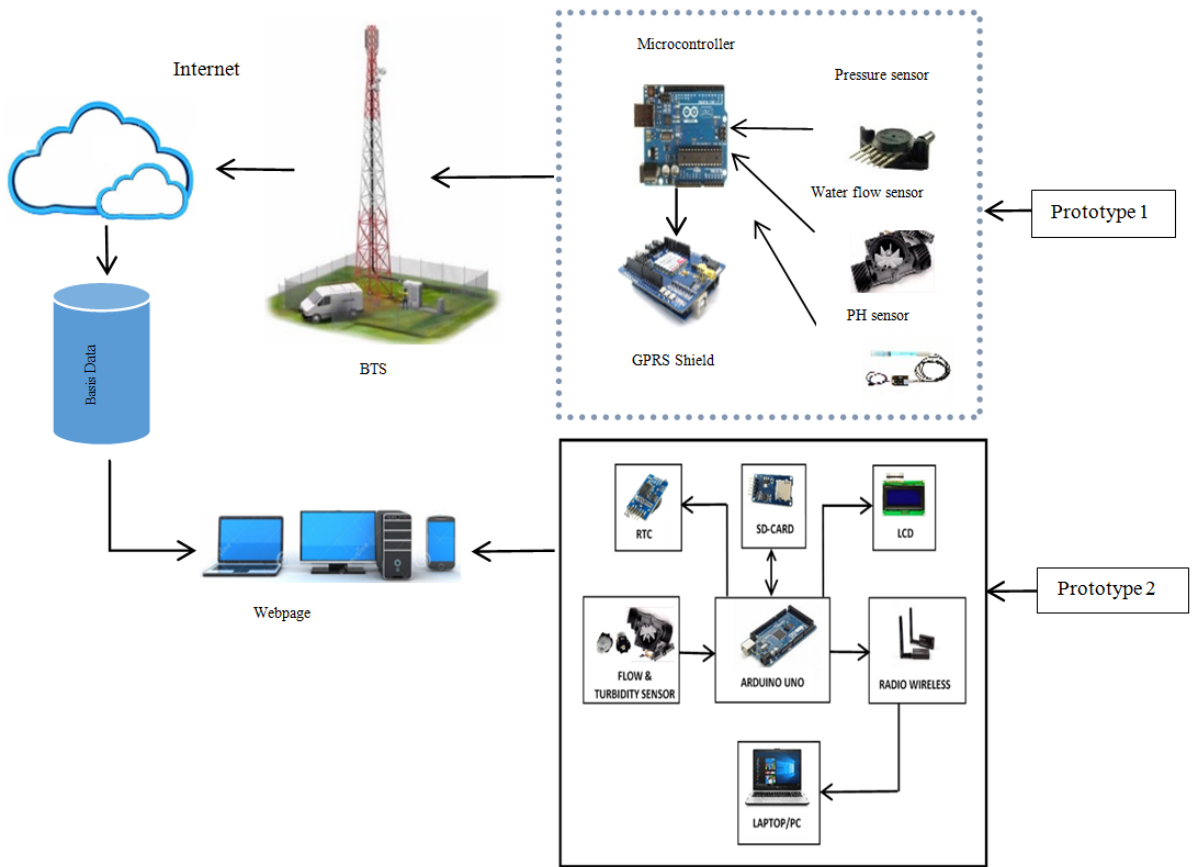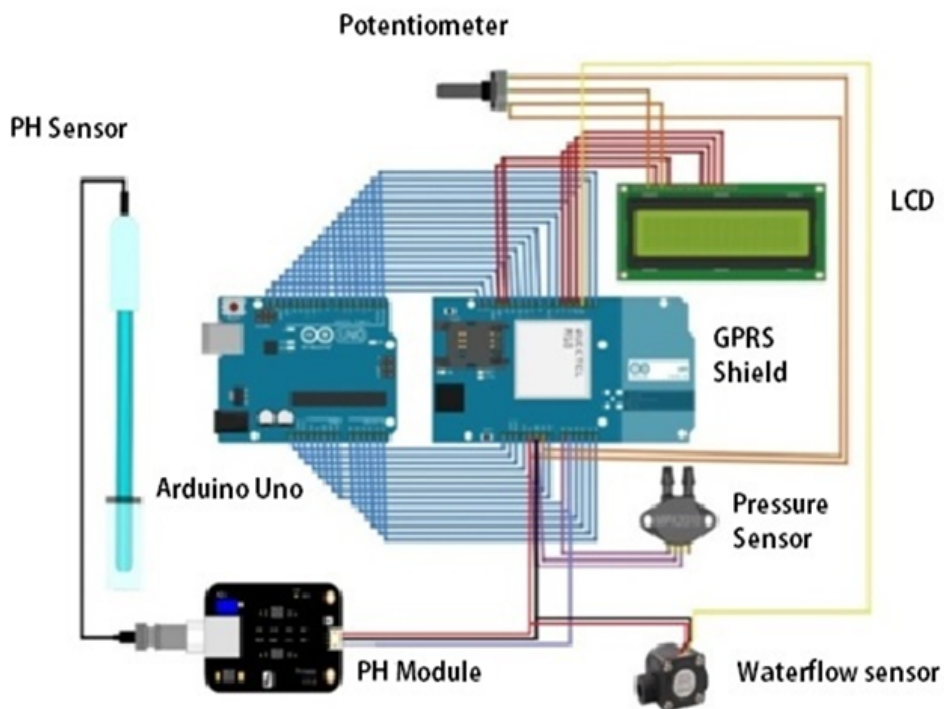

FIGURE 1. Block diagram of the system

FIGURE 2. Prototype 1 design

2.2.2. *Prototype 2.* Microcontroller Arduino UNO is used for both input and output circuit for assembling prototype 2. The input circuit is comprised of a turbidity sensor, G1/2 water flow sensor, RTC DS3231, LCD backlight button, and signal conditioning circuit. Meanwhile, the output circuit is comprised of LCD 20 × 4, MicroSD Card, and 433 MHz Wireless Radio. The YF-S201 water flow sensor has 3 input pins which are DATA, VCC, and GND. DATA pin is connected to *Interrupt* pin of Arduino (D2). Turbidity sensors consist of an IR LED and phototransistor which would gauge the water turbidity. If the level of turbidity is considered high, then the output voltage would be low, and vice versa. This sensor has 3 pins which are DATA, VCC, and GND. DATA pin is connected to Arduino analog pin (A0), VCC is connected to 5V Arduino and GND is connected to GND of Arduino. In the output circuit, LCD 20 × 4 is used to display time, the number of consumption, payment amount, and the level of water turbidity. MicroSD Card is as data storage before it is transmitted to Laptop/PC wirelessly. CS, SCK, MOSI, and MISO pin of MicroSD Card is connected with D50, D51, D52, and D53 in Arduino Mega 2650. The pins are used as the input pins and output pins from the sensor. 3DR Radio 433 MHz is used to transmit data to the computer which has 5 V, GND, TX, and RX pin. 5 V and GND pins are connected to 5 V and GND of Arduino. Meanwhile, TX and RX pin are connected to D20 and D21 of Arduino which are TX0 and RX0 pin. To be able to use 3DR Radio 433 MHz, the settings are made using the 3DRRadio Config software. LIPO battery is also connected to Arduino as a power supply. Figure 3 is a signal conditioning circuit, so the output of the sensor can be detected by ADC of the microcontroller. All of the parts of the device are assembled and connected to one another as shown in Figure 4.
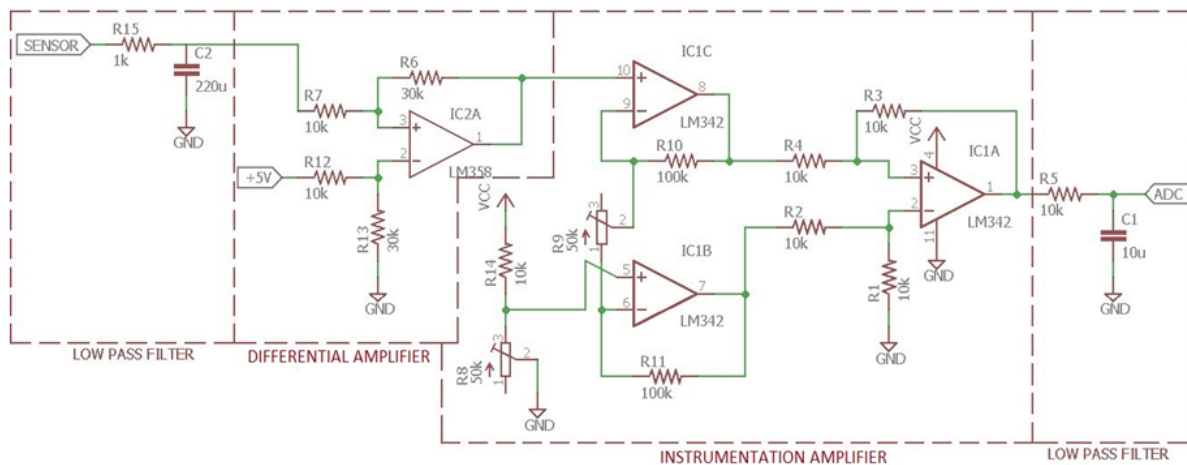

FIGURE 3. Signal conditioning circuit

2.3. **Software design.**

2.3.1. *Prototype 1.* Microcontroller Arduino is controlled using C AVR programming language. The listing program is saved as [*. ino] extension and it has its own compiler which is Arduino IDE. The algorithm of the program can be seen in Figure 5.

From Figure 5(a) it can be explained that Mictocontroller Arduino is first initialized by declaring the pin mode and variable as well as serial communication on the pin both as input and output, so that Arduino can already recognize and read the input is data from the pH sensor, flow sensor and pressure sensor. The data are processed by Arduino and then displayed on the LCD. Furthermore, the data will also be sent to the website via the General Packet Radio Service (GPRS) to display on the website.
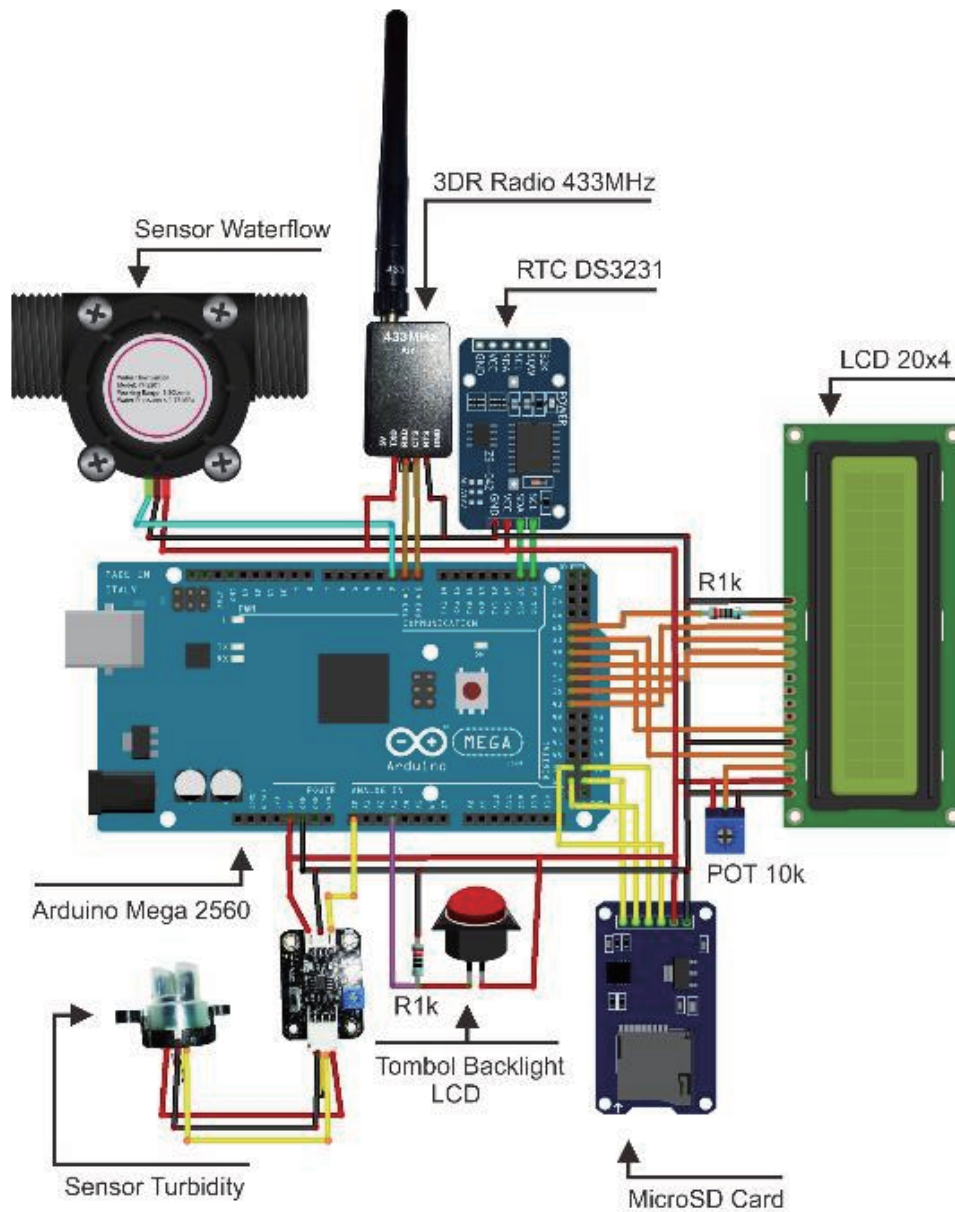
FIGURE 4. Prototype 2 design

2.3.2. *Prototype 2.* The flowchart of software design using Arduino Mega can be seen in Figure 5(b) and to facilitate the user to monitor water debit consumption and water quality, Microsoft Access and Visual Studio are added to the system as well. Microsoft Access is operated to save data (database), while Visual Studio is used to build GUI (Graphical User Interface) with VB.Net programming language. Microcontroller Arduino is first initialized by declaring pin modes and variables and serial communication modes. The serial data in the form of day and date data are read by the RTC and stored on the SD Card, if it is full there will be an erasure command. For readings the LCD pin is set to turn on if the input is HIGH and will turn off every 10 seconds. Furthermore, data from the RTC, flow sensors and turbidity sensors are processed by Arduino and then displayed on the LCD. Furthermore, data will also be sent via Radio to display on the monitor.
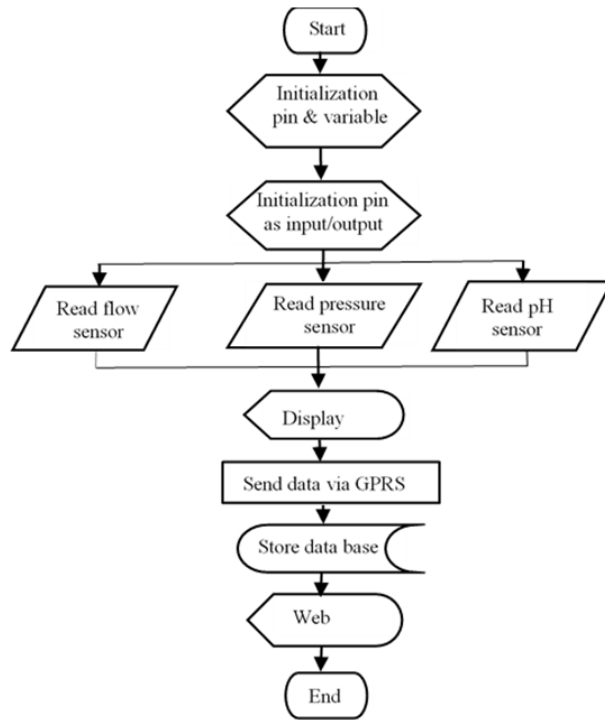
(a) Microcontroller Arduino ATMega 328
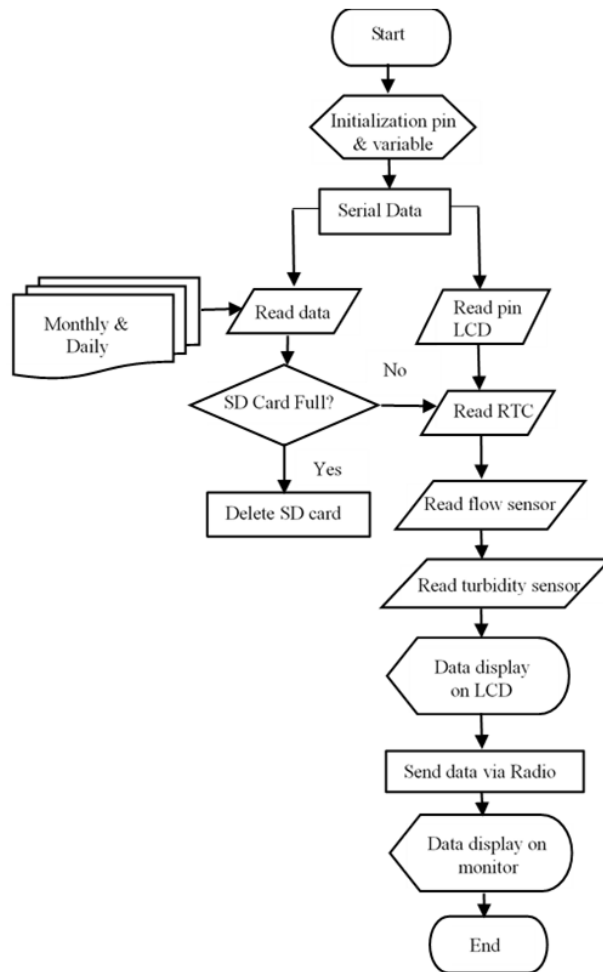
(b) Microcontroller Arduino ATMega 2560

FIGURE 5. Flowchart algorithm program

3. Result and Discussion.

3.1. Prototype 1: Evaluation.

3.1.1. *Pressure sensor, water flow sensor, and pH evaluation.* To test the performance of all sensors used, the results of each sensor will be compared with the available measuring devices as shown in Table 1. From Table 1, the low value of the error, which is only in a range of 0-9.36%, validates that every sensor has operated properly.

TABLE 1. Evaluation result of MPX5700 sensor, liquid flow sensor, and pH

No	Manometer (kPa)	Pressure sensor (kPa)	Error (%)	Measure (ml)	Flow sensor (L/m)	Error (%)	pH test	pH sensor	Error (%)
1	80	81	1.25	425	460	8.23	3	3	0
2	70	70.5	0.71	425	456	7.3	5	5	0
3	60	60.2	0.33	425	501	17.88	7	7	0
4	50	50.1	0.2	425	431	1.41	8	8	0
5	40	40.2	0.5	425	476	12	12	12	0
Mean			0.59	Mean		9.36	Mean		0

(a) Prototype 1   (b) Prototype 2

FIGURE 6. Overall device of prototype 1 and prototype 2

3.1.2. *Overall device evaluation.* Overall device evaluation is intended to evaluate the ability of the system to do real-time monitoring. During the test, the device is placed in the PDAM pipe for ± 2 hours. MPX5700 is installed in the pipe parallel to the manometer, flow meter sensor is installed in series to the water flow in the pipe, and pH sensor is installed in the water reservoir as shown in Figure 6(a), the result can be seen in Table 2. Therefore, the data from the sensors is transmitted to *page.service* in PHP domain and saved in the database with a script command in PHP. From Table 2, it can be seen that the display on the LCD is displayed on the webpage.

3.2. Prototype 2: Evaluation.

3.2.1. *Water flow sensor and turbidity sensor evaluation.* To test the performance of all sensors used, the results of each sensor will be compared with the available measuring devices as shown in Table 3. Based on the measurement, the error obtained is relatively small, which is only in a range of 1.42-2.06%.

TABLE 2. Overall evaluation result

No	Sensor			Web display			Fotovoltaic (V)
	pH	Pressure sensor (kPa)	Flow sensor (L/m)	pH	Pressure (kPa)	Flow (L/Minute)	
1	7	44	11	7	44	11	21.18
2	7	30	8	7	30	8	21.18
3	7	30	8	7	30	8	21.11
4	7	30	8	7	30	8	21.11
5	7	31	8	7	31	8	21.11
6	7	14	1	7	14	1	21.22
7	7	13	1	7	13	1	21.04
8	7	21	2	7	21	2	21.04
9	7	21	5	7	21	5	21.00
10	7	21	6	7	21	6	21.00

TABLE 3. Evaluation result of water flow sensor and turbidity sensor

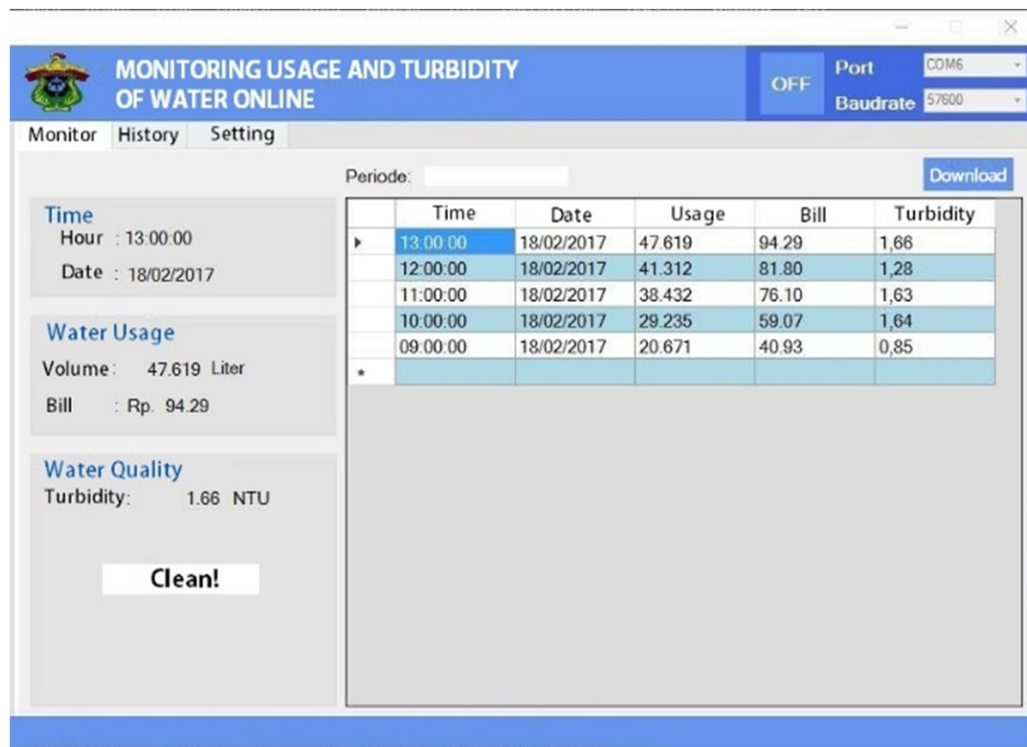| No	Flow sensor (L/h)	Flow meter (L/h)	Error (%)	Turbidimeter (NTU)	Turbidity sensor (NTU)	Error (%)
1	1631	1660	1.747	0.89	0.87	2.2
2	2191	2170	0.968	3.65	3.57	2.1
3	2231	2240	0.402	6.33	6.48	2.3
4	3887	3930	1.094	9.78	9.92	1.43
5	4422	4520	2.168	12.5	12.3	1.6
6	6411	6340	1.119	16.8	16.15	2.08
7	6580	6420	2.492	21.19	20.62	2.69
Mean			1.427	Mean		2.06

FIGURE 7. Display of the measuring result of water debit, consumption, and water turbidity

3.2.2. *Overall device evaluation.* This evaluation is intended to monitor water consumption, the number of payments, and water quality. In the process, prototype 2 is installed in the pipe and operated from 09.00 WITA to 13.00 WITA as shown in Figure 6(b) and the data from the sensor would be displayed on the LCD then the data sent to the application wirelessly as shown in Figure 7. As the result, according to the data that received continuously and thoroughly, it can be concluded that the system runs properly.

4. **Conclusion.** For prototype 1, the system is functioning properly and it can be used to monitor water pressure, water pH and water flow in real time. In hardware evaluation, pressure sensor, pH meter, and flow sensor can measure and serve data of water pressure, water pH, and water flow with the error only in a range of 0-9.36%. For prototype 2, based on the measurement, the error obtained is relatively small, which is only in a range of 1.42-2.06%. The overall system can be operated appropriately according to its design and purposes. The system can facilitate a real-time monitoring of water debit consumption, payment amount, and water turbidity using a VB.Net programming language based application. For further research, a dissolved oxygen sensor device will be added and a water distribution monitoring system will be developed to reach a wider area using the Wireless Sensor Network (WSN).

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