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WATER QUALITY MONITORING IN CITARUM RIVER (INDONESIA) USING IOT (INTERNET OF THING)

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Abstract

This study aims to design an IoT system to obtain the data of Citarum River water quality real time and analyze the water quality based on the World Health Organization (WHO) standard. The two-point locations around the factory sewer passed by Citarum River were monitored using the Internet of Things (IoT) system. The IoT system for water quality monitoring was integrated with pH, turbidity, and TDS sensors. The results show that before the factory sewer, the average value of pH, turbidity, and total dissolved solids (TDS) are 5.281, 1118.768 NTU and 134.44 ppm for pH, respectively. While after the factory sewer locations, the average values were obtained of 2.435, 900.65, and 247.625 for pH, turbidity, and TDS, respectively. It can be concluded that the IoT system can be used to monitor the water quality in the Citarum River and also integrated with real-time monitoring. Although the TDS was found lower than standards, the water quality in Citarum River has not met the standard clean water before as well as after factory sewer location.

Keywords: Citarum River, Internet of things (IoT), pH, Total dissolved solids (TDS), Turbidity.

1. Introduction

As the longest river in West Java (300 km), the Citarum River has a very strategic role such as drinking water sources, aquaculture and tourism. In the last decade, waters around the Citarum River have gradually succumbed to a fair degree of pollution. The main cause of water quality problems in the Citarum River is the over-exploitation of the natural resources around the Citarum River. Chemical waste and oil from the factory around the river are the principal or primary forms of water threatening Citarum's waterway. Moreover, individually, practices also play an important to determine the quality of water. As the longest river in West Java, Indonesia, Citarum River has critical roles such as drinking water sources, aquaculture, transportation, and tourism.

Water quality monitoring is needed for the collection and definition of information on site, in order to obtain precise data and prototype testing intervals to obtain data that can be used to identify current conditions or trends [1, 2]. The main objectives of online water quality monitoring in the Citarum river include measurement of the following parameters such as pH level, Dissolve Oxygen (DO), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS) and turbidity [3]. In addition, this water quality monitoring system also provides analysis of data collected in real-time and suggests the most suitable maintenance process. Therefore, it can be ensuring that safely consumed by human, animals, and plants. Water with a pH level of 11 or higher can cause irritation to the eyes, skin and mucous membranes. Water with a pH level of 4 or below can also cause irritation due to its corrosive effect [4]. Turbidity is the concentration of particles suspended in water. Conductivity indicates the level of water cleanliness, the cleaner the water, the less conductivity. In many cases, conductivity can be directly related to total dissolved solids (TDS).

Traditional water quality measurements include manually collecting water in various watershed locations, storing samples in a central location, and testing samples in a laboratory [5-8]. Mulyanti et al., in a previous study, succeeded in creating a sensor to measure the quality of pond water, namely measuring ammonia levels contained in the pond [8]. Such a methodology is ineffective and lacks reliability due to the unavailability of real-time information, late detection of contaminants, and high costs [9]. Thus, the need for continuous online water quality monitoring is highlighted in [10-16]. Therefore, a water quality monitoring device integrated with the Internet of Things (IoT) system was proposed in this study. All these water parameters will be measured to determine the water quality before can be safely consumed or for aquaculture purposes.

2. Design

2.1. Circuit of IoT system

The proposed work is aimed for water quality monitoring at Citarum River, especially at before and after factory sewerage around the river. The design of the IoT system to monitor pH levels, turbidity, and TDS consists of a microcontroller, modules, and sensors. The detail of the equipment used in this study is shown in Table 1.

Table 1. The equipment of the IoT system for water quality monitoring.

No.	Equipment
Hardware	Cone-cylinder
1	Module Wemos D1 R32
2	Smartphone and laptop
3	Jumper
4	Power bank
5	Mini USB
6	Breadboard
7	pH sensor, turbidity and TDS
Software	
1	Android IDE
2	Adafruit Cloud Storage
3	Fritzing
4	Browser

The flow chart of the working principle of the IoT system is shown in Fig.1. When the battery is connected, the microcontroller initializes to be able to connect to Wi-Fi and reads the library and the configuration will be used to execute the commands received on the microcontroller. The readable value on the sensor is sent to the Wemos D1 R32 module. The analog data is processed into digital data. Wemos D1 R32 is connected to the internet network, sends digital data via Wi-Fi and allocates data to Adafruit Cloud storage, which can be displayed on the user interfaces (Web browser).
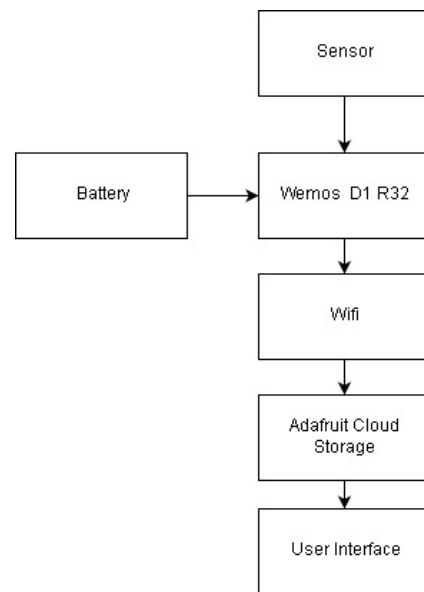
Fig. 1. The flow chart of principle work of IoT system for water quality monitoring.

The IoT system for water quality monitoring that has integrated with sensors is shown in Fig. 2. Wemos D1 R32 module is used to connect one sensor with another sensor. Each sensor used to produce an analog value when 0 to 5 volt voltage was applied. Due to the ADC pin on the D1 R32 can work optimally with an input

voltage of 3.3 volt, a voltage divider is needed which makes the 5 volt to 3.3 volt can be applied to the ADC pin. The resistor of 2.2 kΩ and 1 kΩ were used for the voltage divider circuit, as shown in Fig. 3. The output from each sensor is entered on a different pin after the electrical voltage passing the voltage divider. The pH sensor is installed on the IO36 pin, the turbidity sensor on the IO39 pin, and the TDS sensor on the IO34 pin.
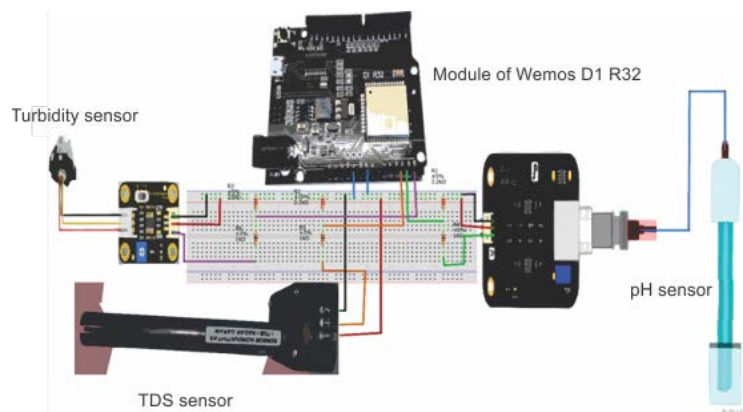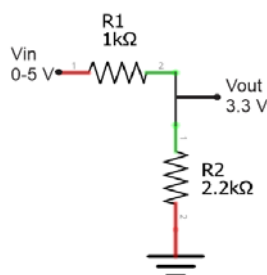

Fig. 2. IoT system used in the research.

Fig. 3. Voltage divider for ADC pin.

2.2. Algorithm

The algorithm for calibrating the Arduino IDE is shown in Fig. 4. The first stage is called the initialization phase that the Wemos D1 R32 module will read all the libraries, as well as the configuration embedded in the Electrically Erasable Programmable Read-Only Memory (EEPROM). The sensor measures the pH, turbidity, and TDS levels which generate ADC value which is converted to their values. The converted value is displayed on the serial monitor on the Arduino IDE.

The algorithm for water quality monitoring after the calibration is shown in Fig. 5. The microcontroller reads all libraries, as well as the configuration that embedded in the EEPROM. The Wi-Fi scanning in the surrounding area and connect to the Wemos D1 R32 and inputting the SSID data and password at the initialization stage. The monitoring from the sensor started when the Wi-Fi connection to the Wemos module in a delay of 10 s. The data from the measurements by the sensor was then uploaded to the Adafruit Cloud. The data was stored in the sensor database located on the web server when the data sent a loop

can occur when the data failed to send and the data return to the Adafruit Cloud. From the sensor database, the data was processed and displayed in the graphic on the Adafruit Web.
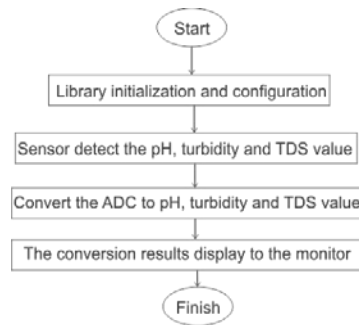

Fig. 4. The block diagram algorithm of pH, turbidity, and TDS calibration in Arduino IDE.
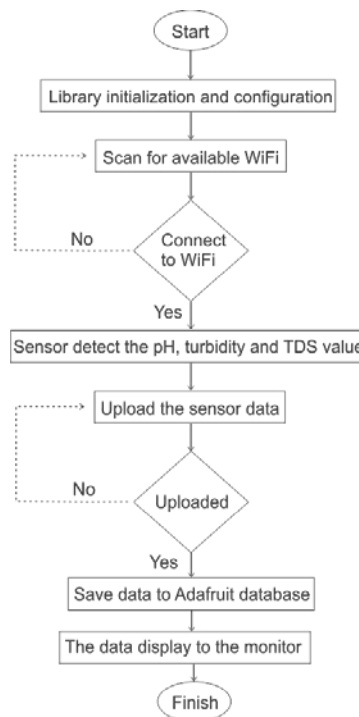

Fig. 5. Block diagram of the IoT system for water quality monitoring.

## 3. Results and Discussion

3.1. Calibration

Three parameters namely pH, turbidity, and TDS are measured using experimental setup. The IoT system integrated with the pH, turbidity, and TDS sensor is shown in Fig. 6. The results are compared with drinking water quality standards defined by WHO. Table 2 shows the safe limit for the parameters considered in this work.

Table 2. WHO standards for drinking water [14].

Parameters Monitored	Quality Range	Units
Turbidity	Cone-cylinder	Ogive-cylinder
pH	13	12.2
Total Dissolved Solids (TDS)	3	7.5
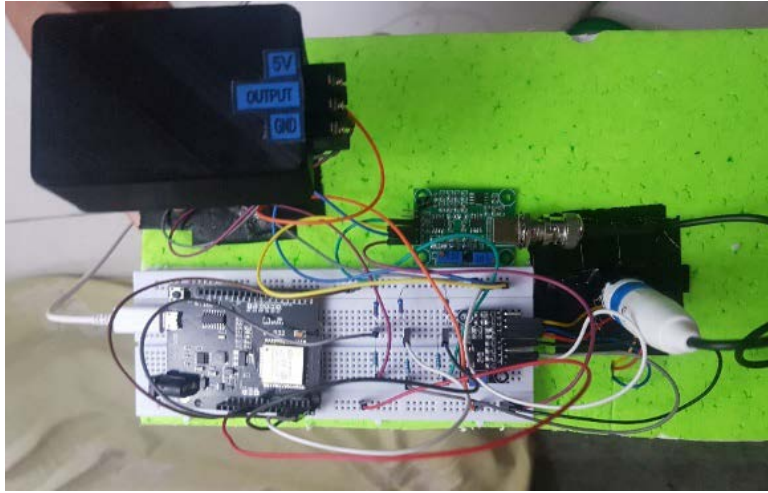
Fig. 6. The IoT system integrated with the pH, turbidity and TDS sensor.

Calibrations of pH, turbidity, and TDS sensors were carried out in 3 (three) stages. Firstly, we measured the voltage of the sensor. The averages voltage values resulted are 2.196 volt and 1.855 volt for the pH sensor of 4 and 7, respectively, as shown in Fig. 7. Secondly, we correlated the values of the voltage measured with pH, turbidity, and TDS to obtain the equation as shown in Fig. 8. In order to convert the values of pH, turbidity, and TDS, the substitution process was required. From the above calibration process, the value differences (error) were found. For example, from the result of pH sensor calibration, we found the error of 0.00375 and 0.006627 for 4 and 7 of pH, respectively. The last step was to substitute the equation for the Arduino IDE coding in order to yield the values of pH, turbidity, and TDS, which shown in Table 3.
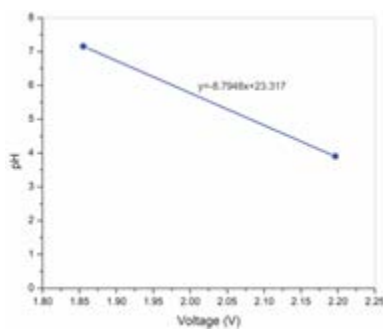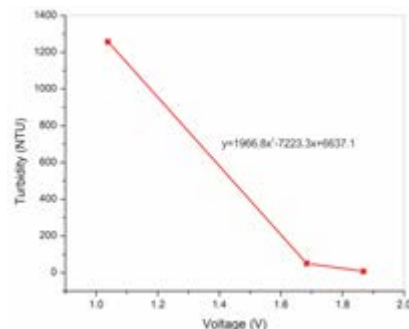
(a) pH.   **(b) Turbidity.**
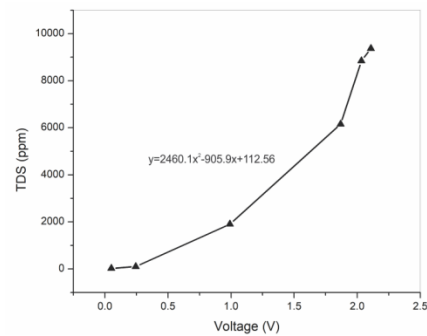
(c) TDS.

Fig. 7. The relationship between the voltage and (a) pH, (b) turbidity, and (c) TDS.

3.2. Locations of quality water monitoring

The location of IoT system for quality water monitoring can be seen in Fig. 8, including before as well as after the factory sewer locations of Citarum River in Katapang area, Bandung (Indonesia).
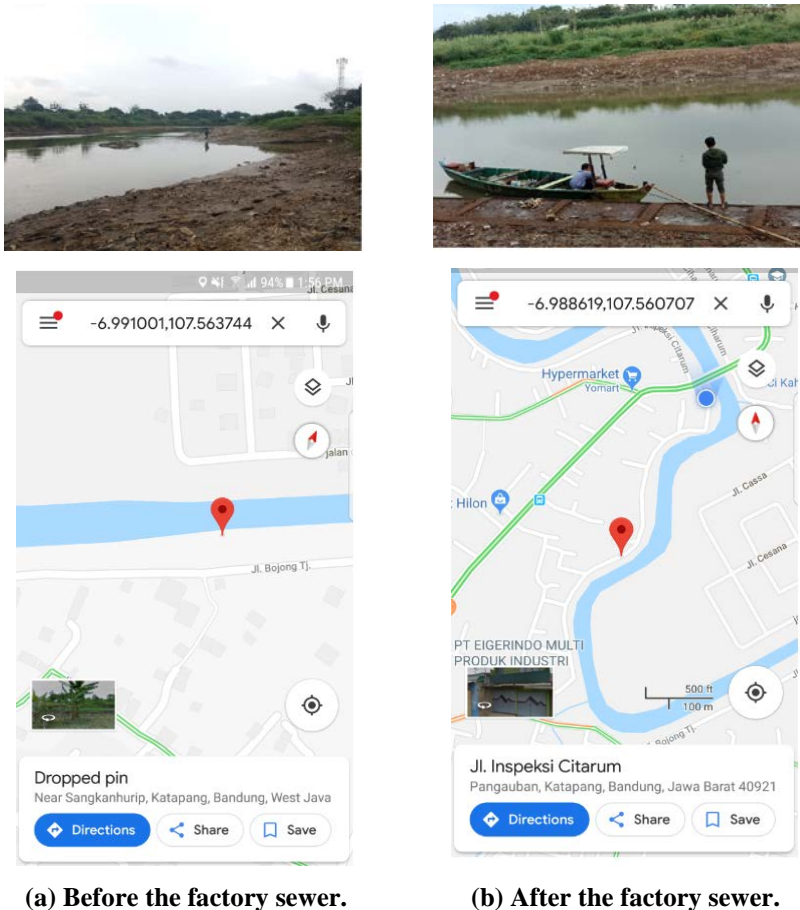
(a) Before the factory sewer.   **(b) After the factory sewer.**

Fig. 8. The location of IoT system for quality water testing.

3.3. Water quality monitoring results

As mention previously, there are two points measurement, i.e., before and after factory sewer locations. Figure 9 shows the measurement results for pH, turbidity, and TDS. The pH value after the factory sewer found smaller than before, which means the quality of the water becomes more acidic. Meanwhile, the turbidity measurements result after the factory sewer tend to be smaller than before, as seen in Table 4. It was most probably because of the rain at the time of measurement in the location before the factory sewer. At last, the TDS value increased by 85.57 %, after the factory sewer location, which means the number of particles dissolved increased in the water of Citarum River caused by the waste material of the factory.
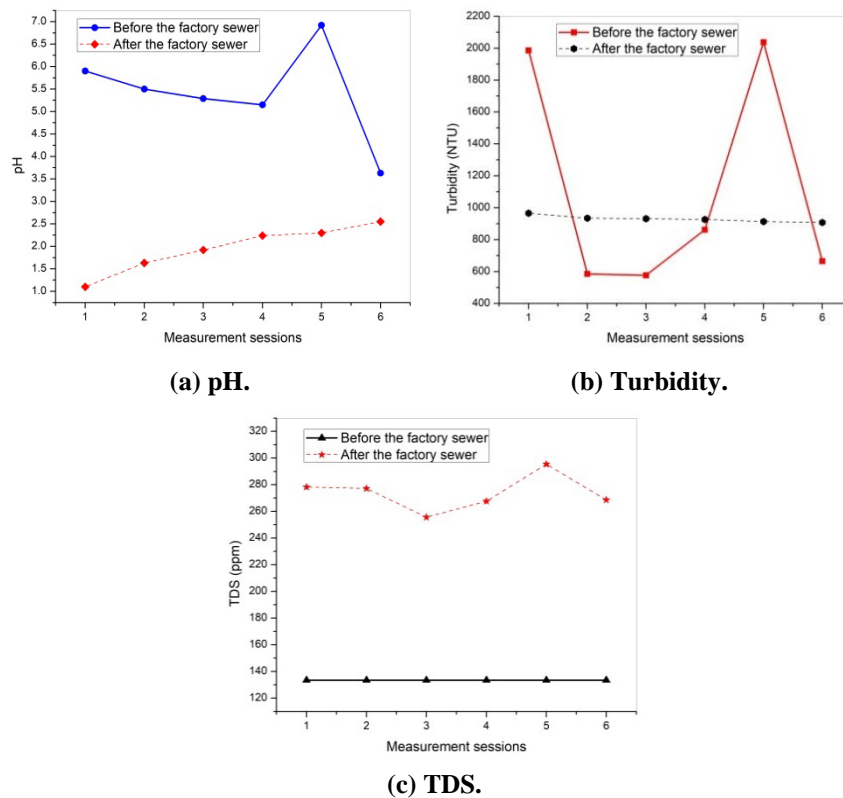

(a) pH.   (b) Turbidity.

(c) TDS.

Fig. 9. The water quality monitoring of (a) pH, (b) turbidity, and (c) TDS.

Table 4. The average of measurement results before and after factory sewer.

	Before factory sewer	After factory sewer	Difference
pH	5.281	2.435	2.846
Turbidity (NTU)	1118.768	900.652	218.116
TDS (ppm)	133.440	247.625	114.185

3.4. Analysis of IoT system

The protocol used in the IoT system was MQTT, which serves to reduce the number of the algorithm on Arduino IDE instead of HTTP protocol. The identification of the protocol can be observed from the algorithm used. Figure 10 shows the

algorithm of the Arduino IDE for the sensor data uploading. There are algorithm "connected", "disconnected" and "publish" indicating that protocol used in the MQTT protocol. In the line 2-16 define each character that use the algorithm for uploading the data to the "web server".

```
#include "Adafruit_MQTT.h"
#include "Adafruit_MQTT_Client.h"
#include <WiFi.h>

#define AIO_SERVER      "io.adafruit.com"
#define AIO_SERVERPORT  1883
#define AIO_USERNAME  "lizard21"
#define AIO_KEY   "7d11ba6d68fd4a38aa76b5a55845631f"
WiFiClient client;

Adafruit_MQTT_Client mqtt(&client, AIO_SERVER, AIO_SERVERPORT, AIO_USERNAME, AIO_KEY);
float calibrationPH = 23.317;
float calibrationTDS = 112.56;
float calibrationTBD = 6637.1;
const int analogInPinPH = 36;
const int analogInPinTDS = 34;
const int analogInPinTBD = 39;
int sensorValuePH = 0;
int sensorValueTDS = 0;
int sensorValueTBD = 0;
unsigned long int avgValuePH;
unsigned long int avgValueTDS;
unsigned long int avgValueTBD;
float b;
int buf[10], temp;
int  K;
```

Fig. 10. Algorithm of Arduino IDE for the sensor data uploading.

The function of an "#include" algorithm is to enter the library that used to shorten the algorithm in the Arduino IDE. Meanwhile an "#define" algorithm has a function to define a character with another character, such as: AIO SERVER is defined as io.adafruit.com. Furthermore, the algorithm "float", "int", "cons tint" and "unsigned long int" mean the classification of certain characters, such as "calibration PH" which is classified into float category. The algorithm contained in the void setup was executed once for each data upload to the Wemos D1 R32 module. The algorithm of serial begin has a function to determine the number of baud rates. In this study, 9600 baud rates were used which means that data could be sent up to 9600 bits per seconds. Furthermore, the Wemos disconnects the Wi-Fi network for 3 seconds and connects with SSID:wifi x and password from Wi-Fi. When the Wi-Fi connection, in the serial monitors appears "WL Connected" and the IP that used.

Figure 11 shows the method used to connect Arduino to the internet via Wi-Fi. Wi-Fi connectivity was used because the installation is relatively more comfortable than using radio communication. Radio communication more expensive than Wi-Fi because it requires a transmitter and receiver circuit. Whereas Wi-Fi only requires a router to communicate sensors on this system.

In general, the algorithm used for "void loop" is shown in Fig. 12. The void loop has a function to repeat the algorithm. The number of algorithms is 6 (six) in accordance with the number of samples used to generate the ADC value. When the MQTT is connected to the Adafruit web, the collected data will be uploaded to the sensor database in every 30 seconds which means 10 seconds on each sensor.

```
void setup()
{

Serial.begin(9600);

  WiFi.disconnect();
  delay(3000);
  Serial.println("START");
  WiFi.begin("Wifi x","kambing21");
  while ((!(WiFi.status() == WL_CONNECTED))){
    delay(300);
    Serial.print("..");


  }
  Serial.println("Connected");
  Serial.println("Your IP is");
  Serial.println((WiFi.localIP()));

}
```

Fig. 11. Algorithm of internet connection.

```
void loop(){
  for (int i = 0; i < 10; i++)  {
    buf[i] = analogRead(analogInPinPH);
    delay(30);  }
  for (int i = 0; i < 9; i++)  {
    for (int j = i + 1; j < 10; j++)    {
      if (buf[i] > buf[j])      {
        temp = buf[i];
        buf[i] = buf[j];
        buf[j] = temp;
      }    }  }
  avgValuePH = 0;
  for (int i = 2; i < 8; i++)
    avgValuePH += buf[i];
  float pHVol = (float)avgValuePH * 3.3 / 4095 / 6;
  float phValue = -8.794 * pHVol + calibrationPH;

  if (MQTT_connect()) {
    if (phsl.publish(phValue)) {
      Serial.println("Nilai PH :");
      Serial.println(phValue);
    } else {        Serial.println("Problem in send data.");
    }    } else {      Serial.println("connect to the site.....");
  }
  delay(10000);
```

Fig. 12. Algorithm of void loop.

4. Conclusions

The design of IoT system for water quality monitoring such as pH, turbidity, and TDS parameters has been done. The IoT system can integrate the data and display water quality monitoring in real time. Although the TDS was found lower than standard, the water quality in Citarum River has not met the WHO standard of clean water before as well as after factory sewer locations.

Acknowledgments

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