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by Rina Mardiati

REMOTELY OPERATED VEHICLE (ROV) ROBOT FOR MONITORING QUALITY OF WATER BASED ON IoT

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***Abstract*— Water is a very important element for humans. Clean water needs are always increasing, but the supply is running low due to water pollution. Various factors can affect water quality, including pH, turbidity (NTU), and substances that are dissolved in water (PPM). Therefore, water quality monitoring must be carried out quickly to determine the level of water quality that is around. By utilizing technological developments such as robots and internet of things monitoring water can be done in real time. In this study a robot system was developed to carry out water quality monitoring based on internet of things. This system uses a microcontroller, Arduino. The developed robot system is controlled by using a remote controller. The monitoring system developed uses a pH sensor to measure pH, a turbidity sensor to measure NTU, and a TDS sensor to measure PPM. To monitor, cloud server is used as a data viewer and data store. Cloud service used is Thingspeak. From the results of testing the robot system, the robot can be controlled properly, and the robot can be controlled to a distance of 140 meters with a robot speed of 0.46 km / hour. From the results of testing the monitor sensor, sensor can work well with an average speed of sending data for 30 seconds.**

Keywords*— *Robot, Monitoring, Internet of Things, Sensor, Arduin.

I. Introduction

Water is an element that is very important for human life. However, the supply of clean water on earth is getting low every day. Water quality can be determined by conducting certain tests on the water, including measurement of physical and chemical parameters [1]. The manual system still has many shortcomings, such as requiring a long time, inaccurate data, and delays in delivering information or reports. Therefore we need a tool that can make measurements from a distance. Robots can be used as human aids that can work automatically in providing water quality information in real time. The delivery of water quality information in real time can be done by utilizing the Internet of Things (IoT) technology connected with the sensors.

Robotic technology is widely applied in various areas of life. There are used in the field of industry, observation, education and others [2]. There are several types of robots that are generally divided into two groups namely manipulator robots and mobile robots. Mobile robot is a robot that can move in place even though the mobile robot is also installed manipulator. Mobile robots can be grouped again into three namely land robot, water robot (underwater robot), and Flying robot (aerial robot) [3]. ROV (Remotely Operated Vehicle) is a type of submarine with a mini-size that is electrically controlled from the center, can maneuver according to human command with a hydraulic or electric thruster and operated by someone [4]. This research utilizes ROV robots as a tool bearer to capture water quality data in order to be monitored directly through the Internet.

According to the Coordinator and support action for global RFID-related activities and standardization it states IoT as a global network connection infrastructure, which connects physical and virtual objects through data capture exploitation and communication technology. The IoT infrastructure consists of existing networks and the following Internet development. It offers object identification, sensor identification and connection capability which is the basis for independently established cooperative service and application development, also characterized by high data capture autonomy level, event transfer, network connectivity and also interoperability [5]. Internet of Things (IoT) makes it possible to connect things like sensors and actuators to the Internet [6].

Water quality Monitoring is essential to know whether or not the quality of water is poor. The provision of poor quality water can result in a negative impact on public health, which is the occurrence of various kinds of diseases. Various factors can affect the quality of water, including pH, turbidity, and dissolved substances in water. The physics parameter used in this study is turbidity and Total Dissolve Solid (TDS) then the chemical parameter used is pH.

The pH sensor serves to alter the nonelectric magnitudes in this case it is the degree of acidity (pH) being the electrical magnitude of the voltage [7]. Water pH changes can lead to the smell, taste, and color of the water [8]. Based on regulation of the Minister of Health (PERMENKES) Number 416 year 1990 about the terms and supervision of quality of water that the quality standard of clean water is a pH level 6.5 to 9 [8]. Turbidity meter Sensors are one of the tools to detect water turbidity meter by reading the optical p roperties of the water due to the disperse of the rays and can be expressed as a comparison of light reflected in the light arriving [9]. In accordance with SK MENKES NO.907/MENKES/SK/VII/2002 the maximum number of turbidity rates allowed is 5 NTU [10]. The TDS sensor is a sensor used to measure the Total Dissolve Soil in the water [11]. According to regulation of the Minister of Health of Republic of Indonesia number 492 year 2010 expressed maximum allowable TDS standard is

978-1-7281-7596-6/20/$31.00 ©2020 IEEE

500mg/Liter or 500 ppm [11]. All of these parameters are measured using pH sensors, TDS sensors, and Turbidity sensors.

The research aims to build ROV robots to monitor pH values, PPM, and water NTU using IoT technology. The research utilizes robots to be used as a carrier monitoring tool that will monitor pH, PPM, and NTU data in real time by utilizing IoT. The IoT Platform used in this research is Thingspeak.

II. Research Methods

A. Design of Robot Systems

The robot system uses a microcontroller that is Arduino Nano. The robot will be controlled using a remote control that has a frequency of 2.4 GHz. The Output of the robot system is a DC motor that is controlled using the L298N motor driver. The Robot is designed to float over water. Here Fig. 1 is a robot system diagram block.

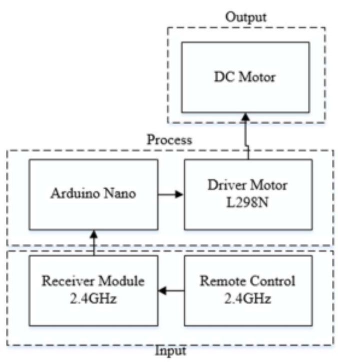

Fig. 1. Block diagram of robot system.

Remote control is used as system input, then Arduino Nano and motor driver L298N are used as system processors, DC motors are used as output of the system. The design of a series of robotic systems can be seen in the following Fig. 2.

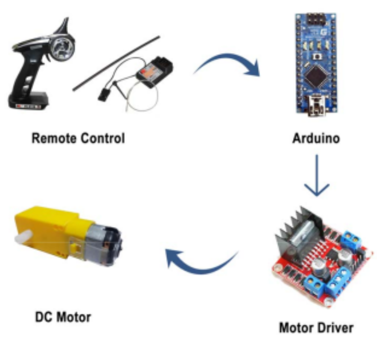

Fig. 2. Design robot system

B. Design Monitoring System

The monitoring system on this study uses the microcontroller Arduino UNO. Sensors used to measure pH values are pH sensors, sensors for TDS value are TDS sensors, and sensors for turbidity meter value are turbidity sensors. The sensor is enabled as a system input. The output of the monitoring system is the display of the cloud platform in the form of sensor output parameter measured. Block monitoring system diagrams can be seen in the following Fig. 3.

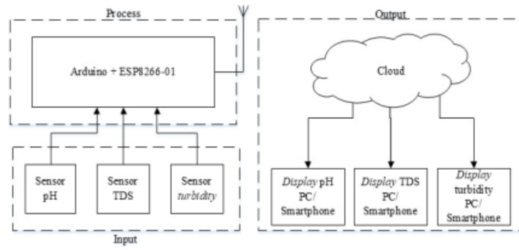

Fig. 3. Block diagram monitoring system.

The Sensor is enabled as a network input, and the Arduino UNO + module ESP8266-01 is enabled as a system processor, and the output of the monitoring system is the display of the parameter values measured on the cloud platform. Here is a Fig. 4 of the design of monitoring system.

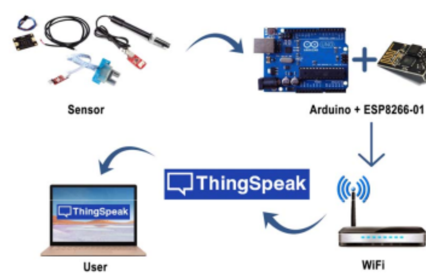

Fig. 4. Design monitoring system.

C. Software Design

Software design starts by creating a program algorithm from both systems. System program algorithms on this research will be presented in the form of flowcharts. The following Fig. 5 is a flowchart of robot system programs.

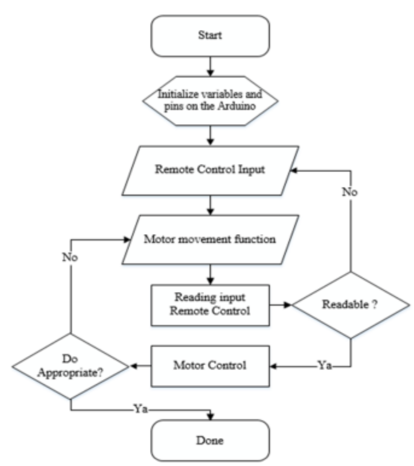

Fig. 5. Flowchart robot system program.

Some of the software used in this research :

- Arduino IDE, used to upload programs to process inputs in order to be the desired output.
- Thingspeak, used for monitoring the readings of the sensor output values used.
- Fritzing, used to create network schemes.

The following Fig. 6 is a flowchart of monitoring system program.

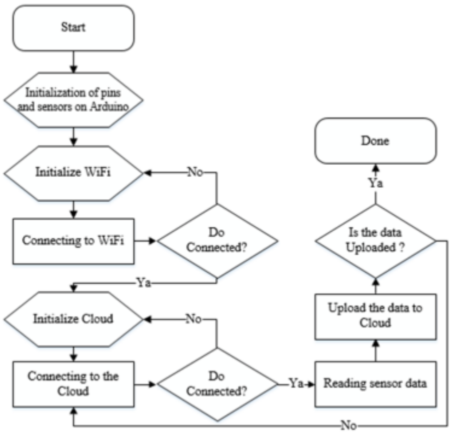

Fig. 6. Flowchart monitoring system program.

III. Testing and Analysis

The design process of both the hardware and software on the robot system and monitoring system has been done. Once all the parts have been designed it will be done the next stage that is the testing phase. In general, this testing phase is meant to know if a tool that has been created can work properly or not. Tests in this study include system implementation sections, monitoring input systems, monitoring systems on the cloud, robotic systems, and integration systems.

A. System Implementation

The components required on the monitoring system are Arduino UNO microcontrollers, pH sensor modules, TDS sensor modules, Turbidity sensor modules, and Wi-Fi ESP8266-01 modules. The hardware implementation of the monitoring system is shown in the following Fig. 7.

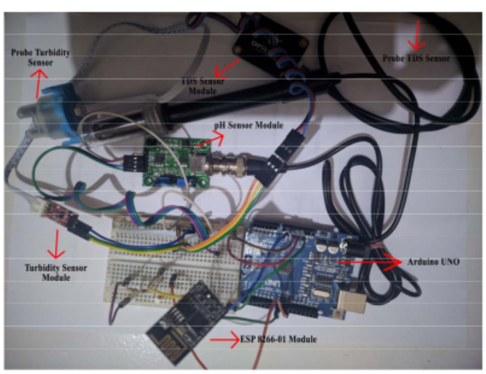

Fig. 7. Monitoring system circuit.

This monitoring system is implemented by utilizing IoT to be able to display sensor values in a cloud server. To turn on the monitoring system, will be used battery 9V as a source of voltage from the monitoring system. After the series of monitoring systems are assembled, subsequent sets of robot systems will be assembled. The components required on the robot system are the Arduino Nano microcontroller, the 2, 4GHz remote control module, the L298N motor driver, the DC motor, and the propeller. Here is Fig. 8 is a circuit of robotic systems.

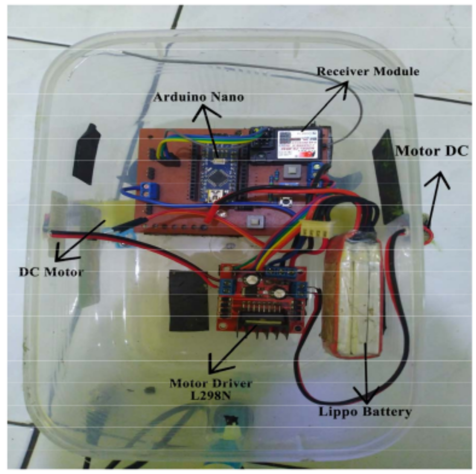

Fig. 8. Robot system circuit.

The series of robot system will be placed in a box for the next assembled and used as a robot that can be controlled by remote control. The robot circuit uses the 12V battery as the main voltage source. Next after both systems are assembled, then the two circuits will be merged as the final system implementation. The following Fig. 9 is integration circuit. Fig. 9 is the front of the robot. Sensors placed on the front of the robot to facilitate the user to know the front side of the robot.

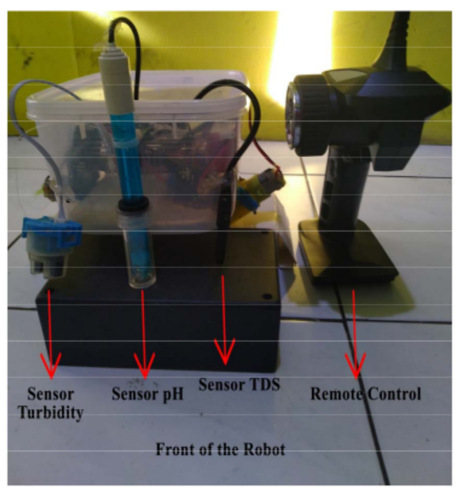

Fig. 9. Integration circuit.

B. Monitoring Input System Testing

An input system test will be performed on the sensor part used. First tested on the pH sensor. Testing will be done by comparing the measurement results of the tool that is pH meter with the pH sensor used. However, before the test is done, the pH sensor needs to be calibrated first. The pH Sensor can be calibrated using a linear equation [12]. The equation is :

$$y = mx + C \quad (1)$$

With, Y is the pH meter measured value, M is the coefficient of sensor calibration, x is the measuring value of the sensor voltage, and C is the sensor constant.

Calibration is done in 2 types of liquids, namely acid fluid and alkaline fluids. The acidic fluid used is water vinegar while the alkaline fluid used is soapy water. At initial measurements the value of Y1 = 4 pH, y2 = 10 pH, x1 = 4.48 Volts and x2 = 3.39 volts. These initial values are inserted into the equation to look for the gradient (m) value so that the pH sensor calibration equation value is y =-5.505* x + 28.66. The calibration equation is subsequently inserted into the program on the Arduino IDE. After obtaining the equation for the calibration of the sensor value, subsequent testing of the sensors on some liquids. The fluids used as testing materials are mineral water, water detergent, water vinegar, soap water, and coffee water. Testing the sensor is done by comparing the value of the reference gauge with the sensors used. The following table 1 is a test result of comparison of pH values from sensors with pH meters.

TABLE 1. COMPARISON OF PH SENSORS WITH PH METERS.

Types of liquids	pH Meter	pH Sensor	Difference
Mineral Water	6.8	6.74	0.06
Detergent Water	10	9.99	0.01
Vinegar Water	4	4.04	0.04
Soap Water	8.1	8.13	0.03
Coffee Water	6.4	6.44	0.04

Testing using this different type of liquid aims to determine if the sensor value with the benchmark measuring instrument is used the same or not. From the tested results, the sensor value of the pH meter is not much different. Next will be done testing the TDS sensor. The TDS sensor test is conducted using the same water samples as the pH test. This TDS Sensor measures the value of dissolved solids (PPM) in a solution. Sensor test value will be compared with the test result of benchmark measuring instrument that is TDS meter. Following table 2 is the test result comparison of PPM value from TDS sensor with TDS meter.

TABLE 2. COMPARISON OF TDS SENSORS WITH TDS METER.

Types of liquids	TDS Meter	TDS Sensor	Difference
Mineral Water	118	123	5
Detergent Water	1188	1193	5
Vinegar Water	109	99	10
Soap Water	867	872	5
Coffee Water	747	759	12

From the results of the tests that have been done, the results of the TDS sensor with the value of TDS meters are not much different from having a small value of difference. The turbidity sensor test will then be tested. This sensor test is conducted by conducting an approach based on research that has been done before by [13]. Based on the results of his research gained that the smaller the value of the voltage, the greater the NTU value gained, which means the clearer the water will be the higher the tension. In contrast, the cloudier the water will be the smaller the tension value [13]. Based on the approach obtained initial value is yl = 0 NTU, y2 = 25 NTU, y3 = 100 NTU, xl = 3.9 volt, x2 = 2.9 volt, x3 = 1.5 volt. Turbidity meter sensor calibration can be done using quadratic equations [14]. The equation is :

$$y = ax^2 + bx + c \quad (2)$$

With Y is the NTU value, a, B is the sensor coefficient, X is the sensor voltage, and C is the sensor constant. The initial value that has been obtained is calculated to obtain a value of a, B, and C. Obtained after calculation result of the calibration equation of turbidity meter sensor y = 11.9048x^2 – 105.9524x + 232.1429. The calibration equation is subsequently inserted into the program on the Arduino IDE. After obtaining the equation for the calibration of the sensor value, subsequent testing of the sensors on some liquids. The fluids used as testing materials are mineral water, water detergent, groundwater, soapy water, and coffee water. The following table 3 is the result of turbidity meter sensor testing.

TABLE 3. THE RESULTS OF TURBIDITY SENSOR TESTING ON DIFFERENT LIQUIDS.

Types of liquids	Sensor Voltage	Turbidity Sensor
Mineral Water	3.9	0
Detergent Water	3.6	5
Soil Water	3.2	15
Soap water	3	21.42
Coffee Water	2.9	25

Looking from the table 3 that the greater the frequency value, the smaller the tension, the smaller the value of turbidity, the greater the value of the tension. This is in accordance with the research that has been [13], where in the research obtained the result of smaller voltage value, the greater the NTU value obtained, which means the clearer the water will be the higher the tension. In contrast, the cloudier the water will be the smaller the tension value. The following is a Fig. 10 is a graph of the relationship between voltages and turbidity meter of tested fluids.

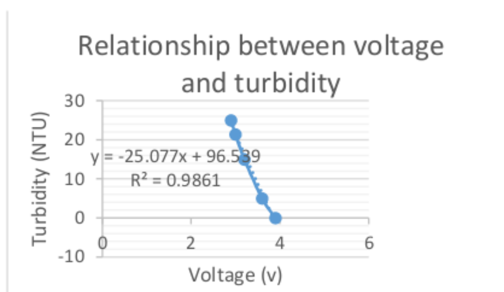

Fig. 10. The relationship between voltage and turbidity of the tested water.

C. Monitoring System on the Cloud Testing

This test is done by testing the cloud display on PC and smartphone. Testing the Cloud monitoring display is done by accessing to the Thingspeak link and logging in and accessing sensor data in Thingspeak with private view. The private view display using the PC can be seen in the Fig. 11.

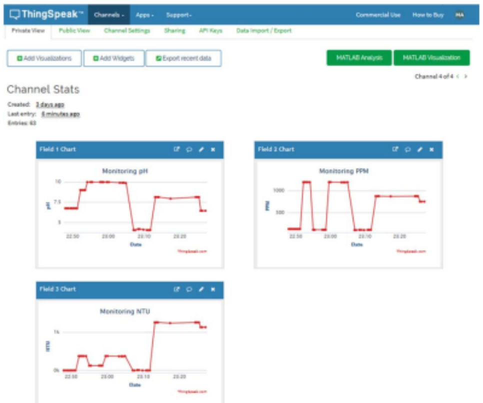

Fig. 11. Thingspeak private view display on PC.

After testing the cloud monitoring display on the PC, the following tests display the cloud monitoring on the smartphone. Here Fig. 12 is a cloud monitoring display on smartphones.

Fig. 12. Thingspeak private view display on smartphone.

D. Robot System Testing

Testing the robot system includes robotic movements, robotic speeds, and robotic connectivity. Testing the robot movements is done to determine the movement of the robot as expected or not. This test was done by operating the robot on water, and then observed movement. The following table 4 is the result of testing robot movements.

TABLE 4. TESTING ROBOT MOVEMENTS.

Experiment	Pressed Key	Expected Result	Test Result
1	Forward	Robots move forward	Robots move forward
2	Reverse	Robot move backward	Robot move backward
3	Right	Robot moves to the right	Robot moves to the right
4	Left	Robot moves to the left	Robot moves to the left

It can be seen in the table 4 that the robot moves as desired. This is in accordance with the expected in engineered the movement of the motor to be able to advance according to the desired order. After testing the robot movement, the robot Speed test was subsequently conducted. This test is done by testing the time that the robot can take to reach a distance of 1 meter. The following table 5 is the result of robot speed testing.

TABLE 5. ROBOT SPEED TEST.

Experiment	Travel time (seconds)
1	7.8
2	7.8
3	8
4	7.8
5	7.9
6	7.7
7	7.9
8	8
9	7.8
10	8.2
Average travel time	7.89

After the test was obtained the result that the robot requires the average time as much as 7.89 seconds to reach a distance of 1 meter. From the test came the result that the robot has a speed of 0.46 km = clock. Robot speed testing has been conducted, further testing of robotic connectivity. This test is done by measuring the connectivity distance between the robot and the remote controller. The distance tested was done by increasing the distance by 10 meters until the robot could not be connected/controlled again by the remote control. The following table 6 is the result of robot connectivity testing.

TABLE 6. ROBOT CONNECTIVITY TESTING.

Experiment	Distance (meter)	Result
1	10	Connected
2	20	Connected
3	30	Connected
4	40	Connected
5	50	Connected
6	60	Connected
7	70	Connected
8	80	Connected
9	90	Connected
10	100	Connected
11	110	Connected
12	120	Connected
13	130	Connected with delay
14	140	Connected with delay
15	$\geq$150	Disconnected

Judging from the test results in the table 6, it can be noted that the +/-connectivity range between the robot and the remote control is 150 meters. The Robot began to experience a slight disconnect of connectivity upon entering distances of 130 meters. The Robot suffered a break in connectivity when entering distances of more than 150 meters.

E. Testing system Integration.

Integration System tests are performed to determine whether the entire tool is created to function as desired or not. The integration system in here is combining a robot system with a monitoring system, but both systems have different functions or controls. Both systems are separate, robots are used as mobilizers so that sensors on the monitoring system can determine the value of the parameters measured from the test point. The test point taken in this test is the side and center point of the tributary in the area of the Citarum River to be conducted monitoring of the measured parameter data. Table 7 tests the robot position system on the edge of the tributary.

TABLE 7. TESTING SYSTEM INTEGRATION WITH ROBOT POSITIONS ON THE SIDELINES OF THE TRIBUTARY.

Experiment	Upload Data time	pH	PPM	NTU
1	14:36:53	7.24	124	28,8
2	14:37:38	7.31	121	28,8
3	14:39:07	7.13	113	28,8
4	14:40:03	7.13	116	25
5	14:41:24	7.24	121	25
6	14:42:18	7.13	122	28,8
7	14:43:10	7.17	113	28,8
8	14:47:35	7.24	121	25
9	14:48:31	7.13	119	28,8
10	14:49:31	7.28	124	25
11	14:49:57	7.08	113	25
12	14:50:39	7.13	116	25
13	14:51:33	7.24	119	28,8
14	14:52:22	7.13	116	28,8
15	14:56:07	7.13	113	25
16	14:56:53	7.24	116	28,8
17	14:57:50	7.31	116	25

The data is obtained from the data logger stored on the Thingspeak. After testing system integration with the position of the robot on the edge of the tributary, further testing system integration with the position of the robot in the middle of the tributary. The following table 8 is the result of testing the robot position integration System in the middle of the tributary.

TABLE 8. TESTING SYSTEM INTEGRATION WITH ROBOT POSITIONS IN THE MIDDLE OF THE TRIBUTARY.

Experiment	Upload data time	pH	PPM	NTU
1	14:58:59	7.53	118	18.1
2	14:59:37	7.64	108	18.1
3	15:00:23	7.71	109	15
4	15:01:07	7.71	118	12.1
5	15:01:52	7.68	115	12.1
6	15:02:20	7.68	115	12.1
7	15:03:04	7.53	109	15
8	15:03:51	7.53	115	15
9	15:04:36	7.64	118	18.1
10	15:05:23	7.68	121	18.1
11	15:06:09	7.53	103	15
12	15:06:51	7.56	115	12.1
13	15:07:37	7.64	118	12.1
14	15:09:05	7.68	118	15
15	15:09:51	7.71	109	15
16	15:10:38	7.64	111	18.1
17	15:11:06	7.64	111	18.1

The data is obtained from the data logger stored on the Thingspeak. Of these two experiments obtained graphs that can be seen on the Thingspeak cloud platform. From the test results it was obtained that the data sending speed was at a range of 30 seconds-2 minutes. The following Fig. 13 is a data view that is uploaded to the thingspeak for system integration testing.

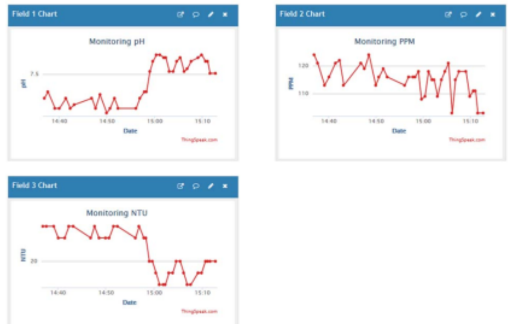

Fig. 13. Uploaded data view in Thingspeak.

IV. CONCLUSION

The robot system has been designed and implemented to be used as a sensor bearer that will take pH data, NTU and PPM water can run well. The Robot has a speed of 0.46 KM per hour. The distance that the robot can reach is up to 140 meters. IoT-based pH, NTU, and PPM-driven water monitoring systems that have been designed and implemented can deliver data with an average 30-second data transfer rate. The system can perform monitoring by displaying the parameter value data of the sensor output used using the Thingspeak cloud server and can also store the sent data for storage in the Thingspeak cloud server. A robot integration system and data retrieval monitoring can run well. The Robot can function as desired. The resulting monitoring system sends data to the cloud server with data transfer speeds between a range of 30 seconds – 2 minutes.

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