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The Monitoring Prototype of Water Physical Condition for Tilapia

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Abstrak.

Ikan nila merupakan organisme air yang sensitif terhadap kondisi air seperti amonia, pH, dan suhu, sehingga nilai-nilai tersebut harus dimonitor untuk menjaga kualitas pertumbuhan ikan. Untuk mengatasi hal tersebut, penelitian ini membangun prototipe yang dapat mengawasi kondisi amonia, pH, dan suhu air pada kolam ikan nila, serta dapat mengirimkan SMS sebagai peringatan apabila keluaran amonia dan suhu air melebihi nilai ambang batas, yakni 1 mg/L untuk ammonia dan 32 oC untuk suhu. Hasil pengukuran dari prototipe yang dikembangkan dibandingkan dengan alat pengukur konvensional yang tersedia di pasaran (HI 715 Ammonia Checker untuk Amoniak dan MEDIATECH 3 IN 1 Quality Water Tester untuk pH dan suhu air). Hasil perbandingan menunjukkan bahwa protipe yang dibangun berfungsi dengan baik dengan batas kesalahan yang wajar. Berdasarkan hasil percobaan di 2 kolam ikan nila (kolam ikan nila A dan kolam ikan nila B), prototipe dapat memonitoring amonia, pH, dan suhu air dengan rata-rata kesalahan pengukuran yang masih dalam batas toleransi yaitu 0,03 mg/L, 0,16 pH, dan 0,62°C pada kolam ikan nila A. Sedangkan rata-rata kesalahan pengukuran pada kolam ikan nila B yaitu 0,04 mg/L, 0,37 pH, dan 0,36°C. Prototipe yang dibangun juga berhasil mengirim SMS peringatan ke ponsel pengguna.

Kata kunci: Amonia, *pH,* Suhu air, *Monitoring,* Pesan teks.

Abstract.

Tilapia is aquatic organism that is sensitive to water quality parameters such as ammonia, pH, and temperature which means that the monitoring of those parameters becomes necessary to ensure the healthy development of the fish. This research developed a prototype which can monitor the condition of ammonia, pH, and water temperature in Tilapia Fishponds, and the send text message as an alert when the ammonia and water temperature exceed threshold values, which is 1 mg/L for ammonia and 32 oC for temperature. The readings from the proposed prototype are compared against conventional tools (HI 715 for ammonia and MEDIATECH 3 IN 1 tester for pH and water temperature). The results show that the proposed prototype recorded readings within the acceptable range of error. Based on the experiments in 2 Tilapia Fishponds (Tilapia Fishpond A and Tilapia Fishpond B), the prototype can monitor ammonia, pH, and water temperature within acceptable error which are 0.03 mg/L, 0.16 pH, and 0.62 Degree Celsius in Tilapia Fishpond A. The average of measurement error in Tilapia Fishpond B are 0.04 mg/L, 0.37 pH, and 0.36 Degree Celsius. The tests also showed that the proposed prototype can send an alert message to user’s cellphone.

Keywords: *Ammonia, pH, Water temperature, Monitoring, Text message*

Introduction

Tilapia is the aquatic organism that is sensitive towards water's quality parameters such as ammonia,pH, and water temperature. Several problems may occur if these parameters exceed that which can be tolerated by tilapia. Ammonia concentration higher than 1 mg/L, for example, may hinder tilapia's growth and may even death [1]. Based on the experience of tilapia farmer in Penajam Paser Utara (Tambak Gumilang), the tilapia will swim upside down if the ammonia concentration is too high. This causes problems in feeding of the tilapia so thus hinders their metabolism. The water temperature may also impact the survival of tilapia [2]. If the water temperature is too high, tilapia will find it difficult to breath. On the other hand, when the water temperature is low they can easily get sick. The water temperature has tight relationship with dissolved oxygen. When the water temperature is high, the dissolved oxygen will be lower, which is why it makes it difficult for the tilapia to breath. Lower water temperature has high dissolved oxygen [3]. The pH is one of the water physical condition that must be concerned by tilapia farmer. It relates with the skin erosion, lethargy, and poses problems in feeding the tilapia. The levels of ammonia, pH, and water temperature are very important for tilapia, which is why these must be of concerns to tilapia farmer. To overcome these problems, this research develops a system to monitor the levels of ammonia, pH, and water temperature in Tilapia Fishpond. By montioring these parameters, the tilapia farmer can identify the water if the water quality is optimal, suboptimal, or even dangerous for tilapia cultivation.

This research has several objectives regarding with the problems in Tilapia Fishpond. This research focus in capability the prototype to detect the ammonia, pH, and water temperature in Tilapia Fishponds. The proposed device can monitor the water physical conditions (ammonia, pH and water temperature) with its outputs displayed in OLED (Organic Light-Emitting Diode) 0.96-inch Display for pH monitoring, and LCD (Liquid Cristal Display) for ammonia and water temperature monitoring. Based on the capability of the sensor to detect the air quality such as (carbon dioxide, benzene, smoke, ammonia, and alcohol), this research is only designed to measure ammonia value in ppm or mg/L. Another objective relates to the feature of the prototype which is to send an alert as text message if the values of ammonia and water temperature in Tilapia Fishpond exceeds the threshold values.

Literature Review

This research designed a prototype which can show the ammonia, pH, and water temperature level in common Tilapia fishpond. It was specifically designed for tilapia cultivation, because every aquatic organism has different parameters they are sensitive to. This research can send an alert if the ammonia and water temperature condition exceed the condition that can be tolerated by tilapia.

The combination of MQ-135 as ammonia sensor with GSM (Global System for Mobile Communications) SIM800L V2 is the new thing also. For the accuracy tool, this research use Hanna Instrument 715 Ammonia Checker as ammonia accuracy tool and MEDIATECH 3 IN 1 Water Quality Tester as pH and water temperature accuracy tool. These comparisons are aimed to show that the prototype can work properly and accurately [6].

Tilapia

In Tambak Gumilang, the farmer cultivates tilapia GESIT (Genetically Supermale Indonesia Tilapia). Unlike other types of tilapia, this particular breed has more dominant males than females so that the reproduction is maximized. The male tilapia grows faster than female. The female is mostly able to grow not more than 250 gram in 5 months. The male, on the other hand, usually can growth up to 500 grams in 5 months. The seed from tilapia GESIT has high demand from other tilapia farmer so that tilapia farmer from Tambak Gumilang cultivates this particular breed. Tilapia can grow in brackish water condition. The brackish water is saltier than freshwater is about 0.5 – 30 ppt (parts per thousand). The physical appearance of tilapia fish can be seen in Fig. 1.

Figure 1. Tilapia fish

Water Quality Parameters

There are three water quality parameters which are very important for tilapia cultivation, namely the ammonia (NH_3) level, pH, and temperature. Each of these parameters must be kept at within certain thresholds to ensure healthy tilapia. According to the BSN (Badan Standardisasi Nasional), the ammonia recommendation for tilapia is not more than 0.02 mg/L [4]. However, since the farmer usually uses compost to grow the microorganism in water to feed tilapia, the ammonia level is usually more than 0.02 mg/L. According to the Denis P. DeLong et al, NH_3 is not recommended greater than 1.0 mg/L [1]. This value is the threshold used in this research.

The pH (Power of Hydrogen) is important aspect for tilapia cultivation. According to Samuel and Moshood, water with high acidity may cause lethargy, bleeding of fins, and skin erosion [5]. If pH level is higher than 8, it will also disrupts tilapia's metabolism and even may cause death. Based on the experience of tilapia farmer in Tambak Gumilang, a pH value in the range of 6-8 is considered optimal for tilapia. Water temperature also plays important role on growth of tilapia. The optimal water temperature that can be tolerated by tilapia is 23-30℃ according to data from BSN (Badan Standardisasi Nasional). Based on the our interview with tilapia's farmer, the tilapia can still can well in 32 ℃ water [7]. So, this research set the optimum value of water temperature which is 25℃ until 32℃. These threshold values are summarized in Table 1.

Table 1. Water Physical Condition for Tilapia

Water Physical Condition	Unit	Optimum Value
Ammonia	℃	≤ 1
Power of Hydrogen	pH	6-8
Water Temperature	mg/l	25-32

The Sensors

There are three sensors used in this research to monitor the water quality parameters in Tilapia Fishpond. The first sensor is MQ-135 (Fig. 2) which is typically used to measure several gases concentration. In this research, MQ-135 is calibrated to measure ammonia concentration. The sensor cannot be used directly because the sensor needs a load resistance from 10 until 47 kΩ between analog pin and ground pin.

Figure 2. MQ-135 sensor

The sensor to measure pH is SEN0161 (Fig. 3) from DFROBOT. This sensor can be used directly without any load resistance, but it cannot be used in water continuously. If the sensor is used in the water continuously, it can shorten the sensor life. The sensor is recommended to use in 6-8 pH [8]. If the sensor measure pH outside the specified range, then the resulting data will not be very accurate.

Figure 3. The pH probe of SEN0161

The last sensor that used this research is DS18B20 (Fig. 4). This sensor can measure the water temperature level in Tilapia Fishpond. The sensor uses additional of load resistance 4.7 kΩ between voltage pin and digital pin on Arduino. If there is no load resistance, the output may read erroneusly.

Figure 4. DS18B20 sensor

Microcontroller

The microcontroller used in this research is Arduino Uno R3 (Fig. 5). Arduino Uno R3 uses ATmega328 as the brain of the system. This board has 14 digital input pins labeled pin 0 until pin 13. For the analog pins, it has A0, A1, A2, A3, A4, and A5. The board can be powered using 9-12 V power supply. To program this board, Arduino IDE (Integrate Development Environment) is used.

Figure 5. Arduino Uno R3

Outputs

There are three kinds of output used this research. For the ammonia and water temperature, LCD (Liquid Crystal Display) 16x2 (see Fig. 6) with I2C Module is used to display the readings. I2C module is used to make the integration with Arduino board simpler.


Figure 6. LCD 16x2

For the measurement of ammonia and water temperature, GSM SIM 800L V2 is added to send an alert if the either the ammonia or temperature exceeds the specified thresholds. This module is shown in Fig. 7.

Figure 7. GSM SIM800L V2

The display for pH is OLED 0.96-Inch (Fig. 8) with the power rating specified as 3.3 V - 5 V.


Figure 8. OLED 0.96-Inch

Methodology

This research compares between common measurement tools and the proposed prototype to ensure that the readings from the prototype is accurate. Hanna Instrument 715 Ammonia Checker is used to measure ammonia in freshwater. For water temperature and pH measurement, MEDIATECH 3 IN 1 Water Quality Tester is used as benchmark reading [9].

The general methodology of this research is as follows. First, data collection is done through observation of tilapia fish ponds, interview and literature review to identify the problems. Based on the results of this step, prototype is developed. In this step, each sensor is calibrated. Then, the proposed prototype is tested against commonly-used measurement tools to ensure the accuracy. The results are then documented and analyzed to draw proper conclusion.

Calibration

The sensors cannot be used directly. It must be calibrated to get output value that relevant with objectives of this research. There several steps to calibrate the air quality into ammonia in MQ-135. First, we must find the point of X1, X2, Y1, and Y2 in characteristic sensitivity on MQ-135 datasheet. The second step finds the gradient using Eq. 1.

$$m=\frac{[\mathrm{Log}(Y2)-\mathrm{Log}(Y1)]}{[\mathrm{Log}(X2)-\mathrm{Log}(X1)]}. \quad (1)$$

Then, we need to find the intersection of the line (b) as in Eq. 2.

$$b = \mathrm{Log}(Y) - (m \times \mathrm{Log}(X)). \quad (2)$$

The voltage from analog pin can be calculateed using the Eq. 3.

$$V_{RL} = \mathrm{AnalogRead} \times \frac{5}{1023}. \quad (3)$$

The next step finds the resistance of the sensor on fresh air or R_o by using Eq. 4. V_C is voltage from Arduino (5V). R_L is load resistor attached to the sensor (10 kΩ).

$$Ro = \frac{(V_C/V_{R_L} - 1) \times R_L}{3.6}. \quad (4)$$

The ratio between R_S (Resistance of the sensor on reaction gas) and R_o (Resistance of the sensor on fresh air) is found by using Eq. 5.

$$\mathrm{Ratio} = \frac{(V_C/V_{R_L} - 1) \times R_L}{R_o} \quad (5)$$

The ammonia value can be obtained by using Eq. 6.

$$\mathrm{Ammonia} = 10^{\{\frac{(\mathrm{Log}\ (\mathrm{Ratio})-b)}{m}\}} \quad (6)$$

pH and water temperature monitoring do not need complex formula for calibration. Water temperature monitoring just uses command to call temperature in Arduino IDE. However pH still needs to be calculated using Eq. 7.

$$pH = VRL \times 3.5 \quad (7)$$

System Design

Working principle of the prototype is represented by the workflow of diagram or flowchart. This research has 3 kinds of monitoring so that there are 3 flowcharts of the system. For pH Monitoring, there are several processes how the prototype gets the data. First, SEN0161 sensor reads the data as analog value. Arduino Uno converts this analog value into pH output value on OLED. The system loops until the device is turned off. The details is shown in Fig. 8.

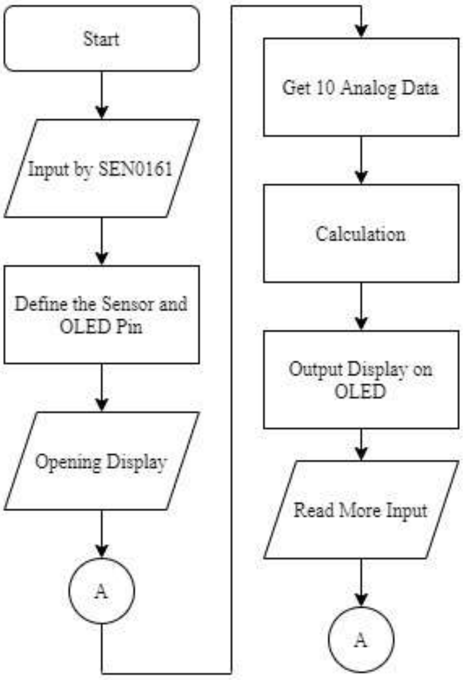

Figure 8. Flowchart of pH monitoring

In ammonia monitoring, there are several processes to get ammonia concentration. First, the sensor reads the data and pass it to Arduino. In Arduino, there is a calculation and conversion from analog data into output value in mg/L or ppm. If the output value of ammonia is more than 1 mg/L the device will send text message to mobile phone as a warning. Otherwise, the sensor simply measures new value. The program always loops until the device is turned off. The details is shown in Fig. 9

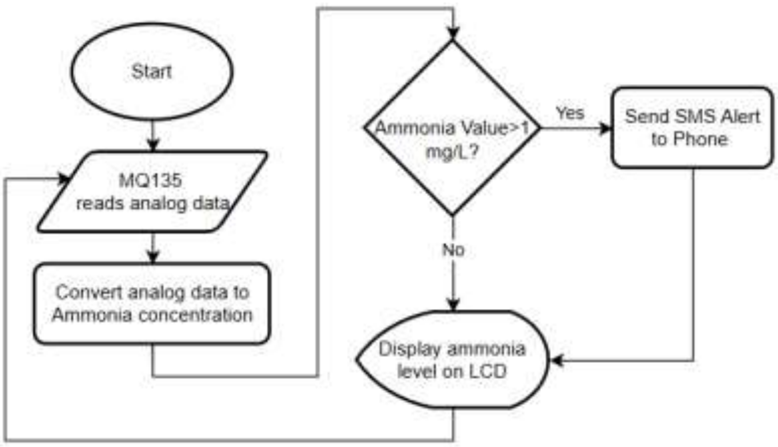

Figure 9. Flowchart of ammonia monitoring

In water temperature monitoring, the temperature is first read by the sensor and passed to the Arduino. The Arduino then convert the reading to data which can be shown on LCD. Then, the temperature is shown on LCD. If the output value of water temperature is more than 32℃ the device will send text message to mobile phone as a warning. The program always loops until the device is turned off. The process can be seen on Fig. 10.

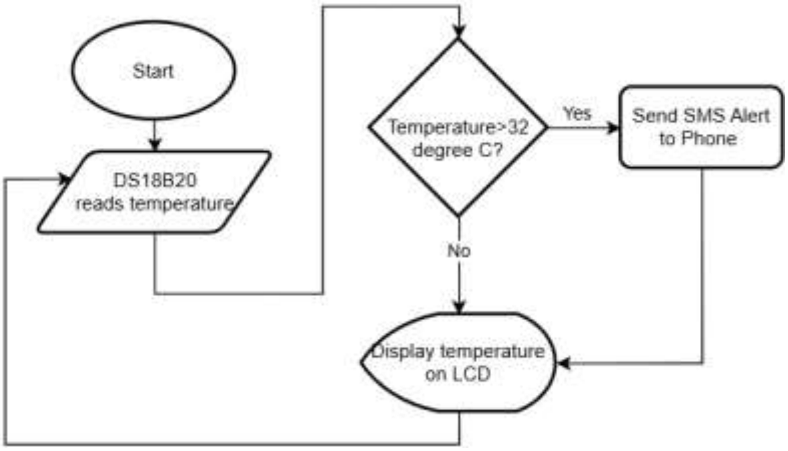

Figure 10. The water temperature monitoring flowchart

Validation

The outputs data from prototype are compared with outputs data from commonly-used measurement tools. Eq. 8 is used to get the error value of the proposed prototype. The average error is obtained using Eq. 9.

$$\text{Error} = \text{protototype data} - \text{accuracy data} \tag{8}$$

$$\text{Mean Absolute Error} = \frac{1}{n}\sum|\text{Error}| \tag{9}$$

In this research, the prototype is said to be accurate if the readings are within the predetermined margine of error. Based on the capability of the sensor and environment condition, this research set the margin of error of ammonia to be ± 0.05 mg/L.. The margin of error water temperature and pH are ± 2℃ and ± 0.5 pH, respectively. These margin of errors are summarized in Table 2.

Table 2. Margins of Error for Each Parameter

Water Physical Condition	Unit	Margin of Error
Water Temperature	℃	± 2
pH	pH	± 0.5
Ammonia	mg/L	± 0.05

Result and Discussion

This research was conducted at Tambak Gumilang located in Penajam Paser Utara, Kalimantan Timur, Indonesia. The prototype is implemented in two tilapia fishponds which have 4.5 meter in length and 2.5 meter in width. The experiments are conducted for 5 days, namely in 20th November 2020, 21st November 2020, 25th November 2020, 27th November 2020, and 5th December 2020.

The Prototype

The prototype uses three microcontrollers, five outputs, and three sensors. For the outputs use two LCD for ammonia and water temperature monitoring, one OLED for pH monitoring, and two GSM SIM800L V2 for ammonia and water temperature monitoring. For the pH is not combined with the

GSM SIM800L V2 because the pH sensor cannot be used in water continuously. The prototype can be seen in Fig. 11.

Figure 11. Proposed Prototype

As for the picture tilapia fishponds, two of them are used as testing sites. These fishponds are located side by side (Fig. 12). They are named fishpond A, and fishpond B.

Figure 13. Tilapia fishpond A and B

Results

Table 3 presents the quantitative result of ammonia monitoring based on implementation in two fishponds Tambak Gumilang. On each one of these sites, the readings from the proposed prototype are compared against the measurement tools. The readings classified into three categories which are *"P"* as prototype readings, *"H"* as the readings from HI 715 Ammonia Checker, and "*M*" as the readings from MEDIATECH 3 IN 1Water Quality Tester.

Table 3. Comparison Ammonia Output between
Prototype and Measurement Tool (HI 715 Ammonia Checker)

Trial	Tilapia Fishpond A			Tilapia Fishpond B		
	***P* (mg/L)**	***H* (mg/L)**	***Error* (mg/L)**	***P* (mg/L)**	***H* (mg/L)**	***Error* (mg/L)**
1	0.61	0.58	0.03	0.31	0.27	0.04
2	0.36	0.40	-0.04	0.32	0.29	0.03
3	0.41	0.38	0.03	0.39	0.34	0.05
4	0.44	0.47	-0.03	0.32	0.35	-0.03
5	0.39	0.41	-0.02	0.33	0.36	-0.03
Mean Absolute			0.03	**Mean Absolute**		0.04

Similar results for pH monitoring is shown in Table 4.

Table 4. Comparison pH Output between
Prototype and Measurement Tool (MEDIATECH)

Trial	Tilapia Fishpond A			Tilapia Fishpond B		
	***P* (pH)**	***M* (pH)**	***Error* (pH)**	***P* (pH)**	***M* (pH)**	***Error* (pH)**

1	6.96	6.97	-0.01	6.38	6.81	-0.43
2	7.71	7.60	0.11	6.24	6.67	-0.43
3	7.76	7.50	0.26	6.76	7.02	-0.26
4	7.44	7.83	-0.39	7.26	7.72	-0.46
5	6.49	6.51	-0.02	7.20	6.95	0.25
Mean Absolute			0.16	**Mean Absolute**		0.37

The results of water temperature monitoring in Tilapia Fishponds from first day until last day are shown in Table 5.

Table 5. Comparison Water Temperature Output between Protype and Measurement Tool (MEDIATECH)

Trial	**Tilapia Fishpond A**			**Tilapia Fishpond B**		
	***P* (℃)**	***M* (℃)**	***Error* (℃)**	***P* (℃)**	***M* (℃)**	***Error* (℃)**
1	28.06	28.90	-0.84	29.56	29.90	-0.34
2	29.00	28.10	0.90	28.94	28.20	0.74
3	28.25	28.00	0.25	28.19	28.00	0.19
4	26.12	25.70	0.42	26.62	27.00	-0.38
5	28.19	28.90	-0.71	27.94	28.10	-0.16
Mean Absolute			0.62	**Mean Absolute**		0.36

Table 6 summarizes the accuracy of the readings in fishpond A. Since each reading is less than the acceptable margin of error, we classify the protype to be accurate in measuring the water quality parameters in fishpond A.

Table 6. Summary of the Accuracy of the Prototype in Tilapia Fishpond A

Water Physical Condition	**Average Prototype Error**	**Margin of Error**	**Work Properly**
Ammonia	0.03 mg/L	± 0.05	Yes
pH	0.16 pH	± 0.5	Yes
Water Temperature	0.62 ℃	± 2 ℃	Yes

Similarly, the readings in fishpond B also shows that the prototype works properly in that pond (see Table 7).

Table 7. The Prototype with Acceptable Error in Tilapia Fishpond B

Water Physical Condition	**Average Prototype Error**	**Acceptable Measurement Error**	**Work Properly**
Ammonia	0.04 mg/L	± 0.05 mg/L	Yes
pH	0.37 pH	± 0.5 pH	Yes
Water Temperature	0.36 ℃	± 2 ℃	Yes

As for the text messaging feature, the proposed prototype is working properly to give a text message as an alert if the output exceeds the threshold values. An example of this is shown in Fig. 14.

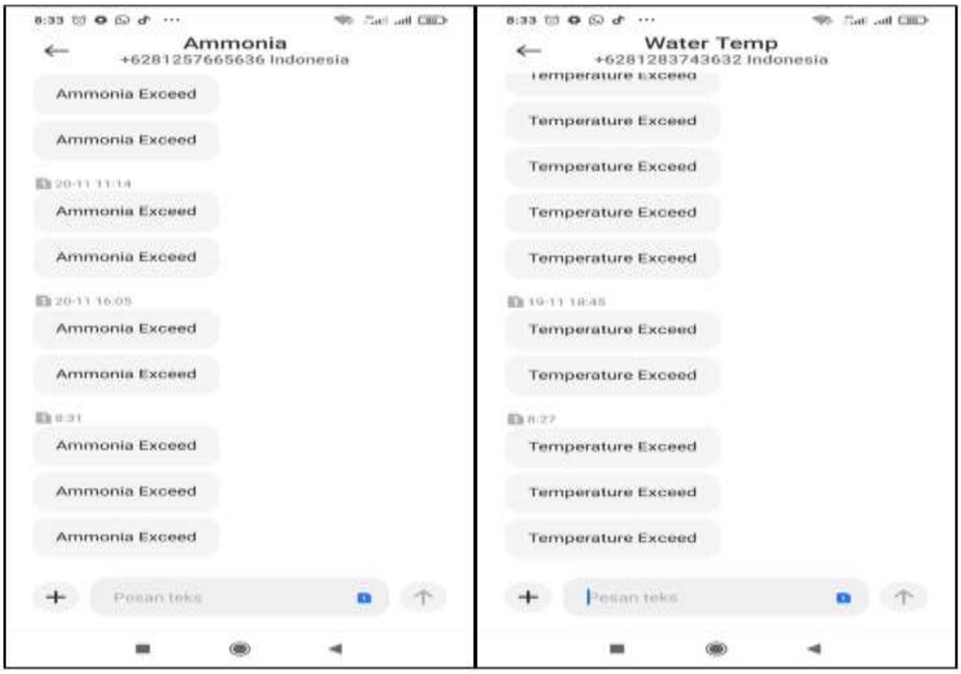

Figure 14. Text messages being sent to user's phone when the readings exceed the threshold value

Conclusions

In this research, a protoytpe of water quality measuremet system for Tilapia fish cultivation has been implemented and tested in two tilapia fishponds in Tambak Gumilang. The prototype is shown to be able to monitor the ammonia, pH, and water temperature in Tilapia Fishponds with average errors of 0.03 mg/L, 0.16 pH, and 0.62 °C in Tilapia Fishpond A and 0.04 mg/L, 0.37 pH, and 0.36 °C in fishpond B. All of these readings are determined to be within acceptable margin of error.

The proposed prototype can also send text message as an alert to user's phone when the readings of ammonia and water temperature exceed the specified threshold values. This way, the farmer can monitor the water quality easily and get notified immediately when the water quality drops, and thus improving the quality of the tilapia cultivation in their ponds.

References

[1] D. P. Delong, T. M. Losordo, and J. E. Rakocy, "Tank Culture of Tilapia," *SRAC Publ.*, no. 282, pp. 1–8, 2009. Available: https://aquaculture.ca.uky.edu/sites/aquaculture.ca.uky.edu/files/srac_282_tank_culture_of_tilapia.pdf (accessed 29 March 2025).

[2] Dinas Perikanan Kabupaten Probolinggo, "Pengaruh Suhu Terhadap Pertumbuhan dan Reproduksi Ikan," 2019. [Online]. Available: http://perikanan.probolinggokab.go.id/download/pengaruh-suhu-terhadap-pertumbuhan-dan-reproduksi-ikan/ (accessed 29 March 2025).

[3] Salmin, "Oksigen terlarut (DO) Dan kebutuhan oksigen biologi (BOD) sebagai salah satu indikator untuk menentukan kualitas perairan," *Oseana*, vol. 30, no. 3, pp. 21–26, 2005. Available: https://ejournal.iwu.ac.id/index.php/biosains_medika/article/download/107/86/ (accessed 29 March 2025)

[4] SNI 6139:2009, "Produksi induk ikan nila hitam (Oreochromis niloticus Bleeker) kelas induk pokok," *ICS 65.150 Badan Stand. Nas.*, 2009. Available: https://benihikannila.com/sni-ikan-nila/ (accessed 29 March 2025)

[5] M. K. Mustapha and S. D. Atolagbe, "Tolerance Level of Different Life Stages of Nile Tilapia Oreochromis Niloticus (Linnaeus, 1758) to Low PH and Acidified Waters," *J. Basic Appl. Zool.*, vol. 79, no. 1, 2018. DOI: http://dx.doi.org/10.1186/s41936-018-0061-3

[6] Islam, Shabiha, et al. "Nutritional Profile of Wild, Pond-, Gher- and Cage-Cultured Tilapia in Bangladesh." Heliyon, vol. 7, no. 5, 2021, p. e06968. DOI: http://dx.doi.org/10.1016/j.heliyon.2021.e06968

[7] McMurtrie, Jamie, et al. "Relationships between Pond Water and Tilapia Skin Microbiomes in Aquaculture Ponds in Malawi." Aquaculture (Amsterdam, Netherlands), vol. 558, no. 738367, 2022, p. 738367. DOI: http://dx.doi.org/10.1016/j.aquaculture.2022.738367

[8] Paredes-Trujillo, Amelia, et al. "Comparative Assessment of Metazoans Infestation of Nile Tilapia (Oreochromis Niloticus) (L.) (Perciformes: Cichlidae) in Floating Cages and Ponds from Chiapas, Mexico." Veterinary Parasitology (Amsterdam: Online), vol. 34, no. 100757, 2022, p. 100757. DOI: https://doi.org/10.1016/j.vprsr.2022.100757

[9] Zhou, Min, et al. "Co-Proliferation of Antimicrobial Resistance Genes in Tilapia Farming Ponds Associated with Use of Antimicrobials." The Science of the Total Environment, vol. 887, no. 164046, 2023, p. 164046. DOI: http://dx.doi.org/10.1016/j.scitotenv.2023.164046