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Design and Build Seawater Temperature and pH Measuring Equipment Microcontroller-Based

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Abstract

The quality of water in a body of water has a very important role in supporting the survival and sustainability of the organisms that live in it. One of the important indicators of seawater quality is the physical and chemical parameters, including seawater temperature and pH. Temperature is a measure of the energy of molecular movement that plays a crucial role in regulating biological processes and the distribution of organisms. Meanwhile, variations in pH values can cause changes and imbalances in CO_2 levels that may endanger marine ecosystems. The purpose of this research is to design and develop a microcontroller-based seawater temperature and pH measuring device using a DS18B20 temperature sensor and a 4502C pH sensor. The results show that the device can detect water quality parameters in real time with an average accuracy of 99% when compared to standard measuring instruments. This research concludes that the designed device is effective, reliable, and easy to use for monitoring seawater quality. The implication of this study is that it can provide a low-cost and practical solution for environmental monitoring, support sustainable marine resource management, and be further developed into an integrated system for wider applications.

Keywords: *Water quality, Temperature, pH, Microcontroller, Sensor*

Abstrak

Kualitas air di suatu perairan memiliki peran yang sangat penting dalam mendukung kelangsungan hidup dan keberlanjutan organisme yang hidup di dalamnya. Salah satu indikator penting kualitas air laut adalah parameter fisika dan kimia, termasuk suhu dan pH air laut. Suhu merupakan ukuran energi gerak molekuler yang berperan krusial dalam mengatur proses biologis dan distribusi organisme. Sementara itu, variasi nilai pH dapat menyebabkan perubahan dan ketidakseimbangan kadar CO_2 yang dapat membahayakan ekosistem laut. Tujuan penelitian ini adalah merancang dan mengembangkan alat pengukur suhu dan pH air laut berbasis mikrokontroler menggunakan sensor suhu DS18B20 dan sensor pH 4502C. Hasil penelitian menunjukkan bahwa alat tersebut dapat mendeteksi parameter kualitas air secara real-time dengan akurasi rata-rata 99% dibandingkan dengan alat ukur standar. Penelitian ini menyimpulkan bahwa alat yang dirancang efektif, andal, dan mudah digunakan untuk memantau kualitas air laut. Implikasi dari penelitian ini adalah dapat memberikan solusi yang murah dan praktis untuk pemantauan lingkungan, mendukung pengelolaan sumber daya laut yang berkelanjutan, dan dikembangkan lebih lanjut menjadi sistem terintegrasi untuk aplikasi yang lebih luas.

Kata kunci: Kualitas air, Suhu, pH, Mikrokontroler, Sensor

Introduction

The survival of organisms that inhabit a body of water is greatly influenced by the quality of the water in that water. To monitor water quality pollution, it is necessary to determine the status of water quality as a reference. Seawater quality is a determining parameter for life in marine waters. In the case of pollution or pollution, the quality of water refers to its presence in the water, including the concentration of harmful substances, chemical residues, or biological contaminants. Many efforts should be made to further improve wastewater collection and treatment capacity for wastewater treatment[1]. There are other factors that must be considered in order for water to be of high quality for marine life, clear water does not always mean good water for marine [2]

Physical and chemical parameters can be used to assess water quality in relation to pollution, as such parameters are significantly influenced by the oxidative ability of the synthesis environment, where the dominant factors for alloying change dramatically [3]. Temperature, color, turbidity, number of dissolved solids, electrical conductivity, smell and taste are examples of physical parameters. Acidity degree or pH, salinity, dissolved oxygen or DO (*Dissolved Oxygen*), heavy metals, CO2, ammonia, nitrogen nitrate, orthophosphate are some of the chemical parameters. Criteria set for mater quality in the first effort will be based largely on physical and chemical parameter[4]. Biological parameters include the presence of bacteria, plankton and so on. Both chemical reactions and biological processes are influenced by temperature, salinity plays a role in the distribution of marine life, water fertility measures are influenced by dissolved oxygen as well as pH [5].

Temperature is a water quality parameter that impacts the life process and the growth and spread of aquatic organisms. Furthermore, variations in water temperature can have broad ecological consequences. Water temperature is one of the most commonly used indicators to assess the impact of climate change on the physical and ecological functioning [6]. Temperature can affect photosynthesis in the ocean in two direct or indirect ways. The direct impact of temperature helps in the control of the enzymatic processes involved in photosynthesis. High temperatures have the direct effect of increasing the maximum rate of photosynthesis, while their indirect effects alter the hydrological structure of the water column and impact the distribution of phytoplankton [7].

Acidity Degree or pH is a water quality parameter that is the level of acidity and determines whether water is in good or bad condition. Its value is determined by calculating the negative logarithm of the concentration of hydrogen ions released in the liquid. As one of the chemical parameters, the pH of the water is important to monitor to maintain the stability of the waters. Changes in the pH value in the waters have a great influence on the organisms in it. In addition, high pH levels can affect the dominance of phytoplankton which in turn affects the amount of primary productivity in the waters [8].

A microcontroller board called Arduino Uno is an ATmega328-based board (*datasheet*). Arduino was an open-source electronics platform based on easy using hardware and software[9]. The Arduino Uno has 14 input pins from digital output, 6 digital output pins can be used as PWM output and 6 analog input pins, a 16 MHz crystal oscillator, a USB port, *a power jack,* an ICSP header and a reset button. Connect the

Arduino Uno board to a computer with a USB cable to activate the microcontroller or turn it on using an AC adapter to a DC adapter or battery [10]

Sensors are devices used to identify symptoms or signals brought by changes in energy including electrical energy, mechanical energy, physical energy, chemical energy, biological energy and other types of energy. To generate a signal, the sensor changes the signal input. The sensor can also use one or more conversions to generate an output signal. The sensor module functions to detect the pH and temperature of the water and produce an analog voltage as its output [11].

Ultrasonic sensors are sensors that can emit sound waves in addition to converting physical quantities (sound) into electrical values and vice versa. Ultrasonic sensors detect objects and measure distance by emitting high-frequency sound waves and analyzing the time it takes for these waves to bounce back from surfaces, enabling accurate non-contact measurement in various conditions. Ultrasonic sensors have become widely used for non-intrusive characterization and measurement of multiphase flows across domains like oil and gas, nuclear, and chemical engineering [12]. There are various components on an ultrasonic sensor. SRF05 is a non-contact ultrasonic distance sensor that can measure distances between 3 cm and 3 m with an output pulse length proportional to the distance of the object. The two ultrasonic sensors of the HC-SR04 are ultrasonic wave-based distance measuring sensors, and both can measure distances up to 400 cm. Finally, the PING ultrasonic sensor can measure objects from 2 cm to 300 cm. This sensor works by sending pulses whose width corresponds to the distance of the object [13].

The purpose of the research is to design a device to detect seawater temperature and pH levels using microcontroller-based sensors. The benefit of this tool is that it can be used to obtain information on temperature and pH levels in a water. With this tool, seawater quality can be monitored continuously and the data obtained can be used to help maintain the balance of the seawater environment.

Method

a. Time and Place of Research

The research activities were carried out on March - April, 2023 at the Oceanographic Research Center, National Research and Innovation Agency (BRIN) Jakarta. This location was chosen to support collaborative research efforts which align with the agency's broader objectives. Basicly, BRIN aims to improve the quality and quantity of researchers in Indonesia by integrating researchers into its system [14].

b. Tools and Materials

The tools and materials used in the study are in Table 1:

Table 1. Tools and Materials

No.	Tools and Materials	Uses
1	Sketchup App	To design seawater temperature and pH measuring devices
2	Arduino IDE Applications	To program water temperature and pH measuring instruments

3	Fritzing Applications	Create a schematic set of tools
4	Arduino Uno	As a program store of the sensor
5	LCD + I2C 16x2	Displays data from temperature and pH sensors
6	Sensor Suhu DS18B20	Measuring the temperature of the waters
7	Sensor PH 4502C	To detect the pH of water
8	*Data Logger Shield*	To receive and store sensor data
9	Green PCB 9x15 cm	Organizing sensor components

c. Working Procedure

The stages carried out in this research activity include:

1. Learn the basic components of seawater temperature and ph measuring devices

   This stage studies the basic components of the tool that is made, namely the pH sensor and the temperature sensor. A pH sensor is a sensor used to determine the level of acidity. A temperature sensor is a temperature sensor that can be connected to a microcontroller. Common types of temperature sensors suitable for microcontroller integration include thermistors, the DS18B20 digital sensor, and the LM35 analog sensor, all of which can be connected directly to microcontrollers such as Arduino or PIC via analog or digital interface pins [15].

2. Tool design creation

   At this stage is the making of the design of the tool to be made. Design creation using 3D design applications. The application that will be used is the *sketchup* application, where *sketchup* is a simple and effective 3D modeling and image design program.

3. Program creation

   At this stage is the creation of a program, namely Arduino uno programming. The program uses Arduino IDE software. The Arduino IDE is written in the Java programming language with *the Program Editor*, *Compiler and Uploader components*.

4. Tool assembly

   At this stage is the assembly of the tool where each electronic component is connected to each other according to the pins of the foot and the electronic path.

5. Testing

   The testing stage is the trial stage of the tool that has been made. Trials are carried out in laboratories and marine waters with a minimum of 30 tests to obtain valid or accurate results.

d. Microcontroller Board

A microcontroller board called Arduino Uno is an ATmega328-based board (*datasheet*). The Arduino Uno has 14 input pins from the digital output, 6 digital output pins can be used as PWM output and 6 analog input pins, a 16 MHz crystal oscillator, a USB port, *a power jack,* an ICSP header and a reset button [16]. The Arduino Uno board is connected to the computer with a USB cable to activate the microcontroller. The Arduino board can be seen in figure2.

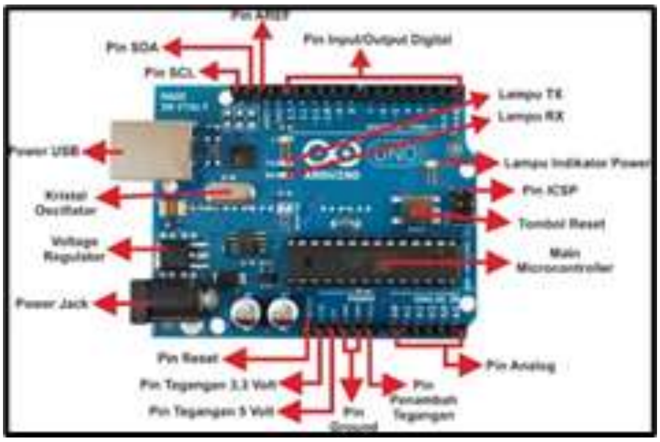

Figure 2. Arduino Board

e. Sensor Module

The sensor module functions to detect the pH and temperature parameters of the water that produce an analog voltage as its output. Therefore, the reading value must be entered into the program code formula in order to be converted. Applications for this sensor module include hydroponics, aquaponics, environmental water testing and others. pH sensors are used to measure the pH of a water, which is a number that shows how acidic or alkaline a solution is. The pH value range is between 0 - 14. The pH measuring sensor is called the 4502C sensor [17].

Figure 3. Ph Measuring Sensor, 4502C

Temperature sensors are used to measure the temperature of a water. This sensor is called a waterproof DS18B20 sensor. A waterproof DS18B20 temperature sensor is widely used for measuring temperatures in liquids, including water, due to its sealed stainless steel housing that ensures water resistance and accurate readings [18]. The amount of temperature of a body of water depends on the condition and location of the water [17].

Figure 4. Temperature Gauge Sensor, DS18B20

f. Data Analysis

The data analysis carried out in the manufacture of seawater temperature and pH measuring instruments is an analysis of errors and accuracy. The data used was data from 30 experiments with the device with a thermometer and pH *buffer* and then analyzed to find out how far the data deviations occurred in each experiment. The analysis to find the error value on this measuring tool uses the following formula: [19]

$$\text{Tool Error (100\%)} = \left(\frac{Xi - Yi}{Yi} \right) x\ 100\% \qquad \text{........(1)}$$

Where:

Xi = value on the measuring instrument

Yi = value on the comparator

The analysis in finding the percentage on this measuring tool uses the following formula: [19]

$$\text{Tool Accuracy (\%)} = 100\% - \text{Tool Error (\%)} \qquad \text{...........(2)}$$

Results and Discussion

This seawater temperature and pH measuring device is made with a DS18B20 temperature sensor, a 4502C pH sensor and *a Data Logger Shield* which is used to determine the quality of the waters. The results can be displayed through LCD in the form of digital results and can be stored on an *SD Card*.

a. Tool Design Results

At this stage, the tool design stage is carried out using a 3D design application, namely *a sketchup application*. The design of this water quality measuring device uses two sensors. The sensors used are temperature sensors and pH sensors and use a box as a protector of the components of the tool. The results of the design that have been made using *the sketchup* application can be seen in figure 5.

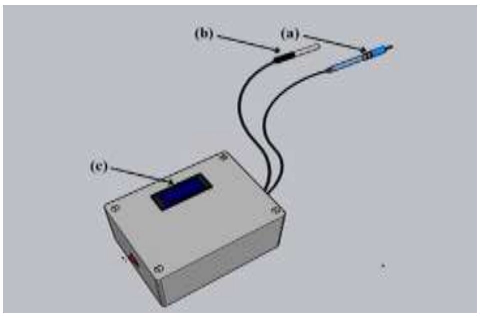

Figure 5. Tool Design. (a) pH Sensor (b) Temperature Sensor (c) LCD

Figure 5 is the result of the design of the tool made using *the sketchup application*. The components of the tool located outside the component box, are (a) pH sensor, (b) temperature sensor, (c) LCD monitor screen that displays sensor data. The design of the top, front and side visible tool is shown in figure 6.

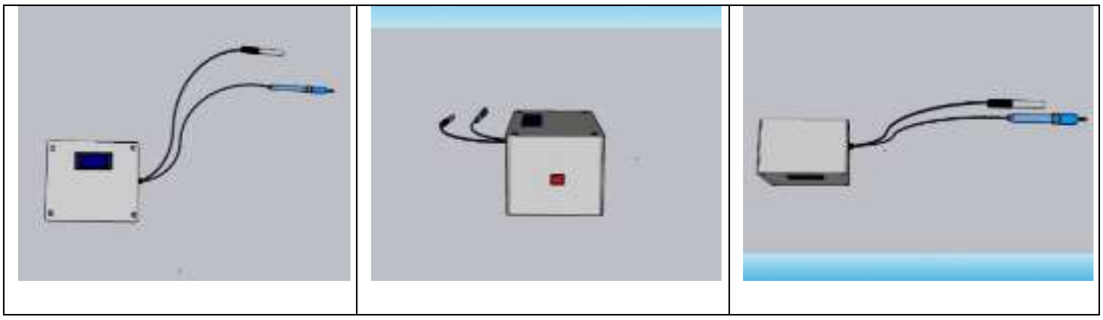

Figure 6. Tool Design: (A) Top View, (B) Front View, (C) Side View

b. Schematics Tools

Figure 7 is a schematic series of temperature and pH measuring instruments where in the image there are (1) Arduino Uno, (2) *data logger shield*, (3) DS18B20 temperature sensor, (4) pH 4502C sensor, (5) LCD with I2C, (6) 9 Volt box battery, (7) *switch on off* and (8) *resistor*.

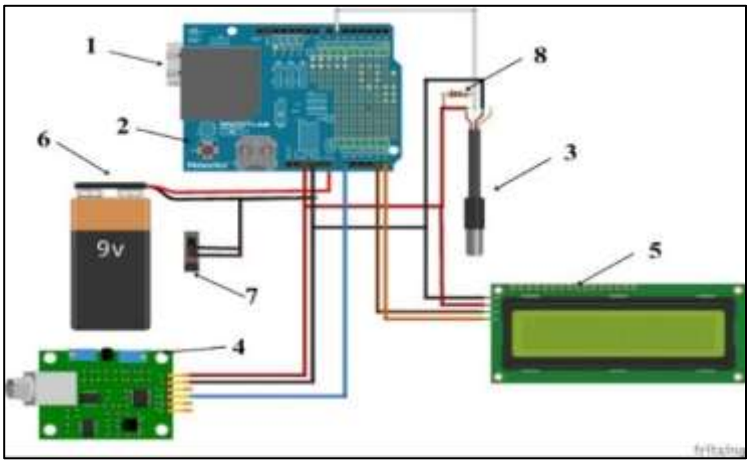

Figure 7. Schematic of the Design and Construction of Seawater Temperature and Ph Measuring Instruments

In the series of tools in figure 7 there is a component, the first is the Arduino Uno which is directly connected to the *data logger shield*. On the temperature sensor between the vcc pin and the digital pin is connected with *a pull-up resistor* to amplify the signal to be read by the Arduino pin. On the pH sensor the vcc pin is connected with 5V on the Arduino, the sensor is connected with the Arduino gnd and the Po pin on the pH sensor is connected on the A0 analog pin on the Arduino. Then the sensor results to be able to appear on the LCD, the gnd, vcc, pins on the LCD are connected to the Arduino, the sda pins on the LCD are connected to the A4 pin on the Arduino and the scl pin on the LCD is connected to the A5 on the Arduino.

In order for the tool to be used, a battery is required as *a power supply*. The battery used is a 9-volt box battery where the gnd leg on the battery is connected with the gnd leg on switch *off* to the Arduino and the vcc leg on the battery is connected to the vin leg on the Arduino.

c. Tool Assembly Results

The manufacture and assembly of seawater temperature and pH measuring equipment components is the process of uniting the components of the equipment to be made. In its assembly, several stages are needed. The tools and materials that have been obtained such as Arduino Uno, temperature sensor, pH sensor and *Data Logger Shield* are then connected. The connection of the components on the Arduino also needs to match the desired output. For example, in the temperature sensor you need a jumper between the Arduino and the sensor connected to the 5V pin, then the sensor must be the same, another example is the ground adjustment on the Arduino with the sensor. The results of the design and electronic paths of the temperature and pH measuring device can be seen in Figure 8 and Figure 9.

Figure 8. Tool Component Design Results

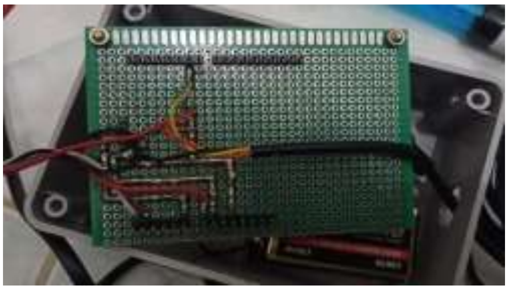

Figure 9. Tool Electronics Line

The array on the Arduino Uno used, has 14 input pins or digital outputs (6 pins can be used as PWM outputs), 6 analog input pins, using 16 MHz crystals, *power jack*, USB connection, ICSP header and reset button. The following are the results of the tool that has been made, which can be seen in figure 10.

Figure 10. Tool Manufacturing Results

d. Tool Testing

Tool testing is carried out to find out the system that operates on the device, where temperature sensor testing is carried out by comparing existing devices, namely thermometers and pH sensors with *pH buffers* to calibrate sensors. Testing of temperature and pH measuring instruments was carried out at the Laboratory of the Oceanographic Research Center, National Research and Innovation Agency (BRIN) Ancol Jakarta and testing of the equipment was carried out 30 times.

e. Temperature Sensor Test Results

In the temperature sensor test at the Laboratory of the Oceanographic Research Center, National Research and Innovation Agency (BRIN) Jakarta, 30 data were obtained from the measurement of the temperature sensor. At the same time, measurements were also taken with a thermometer. The test results can be seen in Table 2.

Table 2. Temperature Sensor Measurement Results

No	Time	Temperature (Sensor) (X1)	Temperature (Thermometer) (X2)
1	2023-05-08	26.9	26
2		26.7	26
3		26.7	26
4		26.6	26
5		26.6	26
6		26.6	26
7		26.6	26
8		26.5	26
9		26.5	26
10		26.6	26
11		26.5	26
12		26.4	26
13		26.5	26
14		26.5	26
15		26.4	26
16		26.4	26
17		26.4	26
18		26.5	26
19		26.4	26
20		26.4	26
21		26.3	26
22		26.3	26
23		26.3	26
24		26.3	26
25		26.4	26
26		26.4	26
27		26.3	26
28		26.4	26
29		26.3	26
30		26.3	26
	Total	820.6	780
	Maximum	26.9	26
	Minimal	26.3	26
	Average	27.3	26

In temperature sensor testing to find the error percentage of instrumentation tools using equation (1) as follows:

$$\text{Tool Error (100\%)} = \left|\frac{820.6 - 780}{780}\right| \times 100\% = 0.05\%$$

From the results of the measurement above, the result of tool error is 0.05%. To find a comparison of the percentage tool, use equation (2) as follows:

$$\text{Tool Accuracy (\%)} = 100\% - \text{Tool Error (\%)}$$
$$= 100\% - 0.05\% = 99.95\%$$

f. pH Sensor Test Results

In the pH sensor test at the Laboratory of the Oceanographic Research Center, National Research and Innovation Agency (BRIN) Jakarta, 30 data were obtained from pH sensor measurements. The test results can be seen in Table 3.

Table 3. Ph Sensor Measurement Results

No	Time	Buffer pH (X2)		
		4.01 (Keasaman)	6.86 (Netral)	9.18 (Basa)
1	2023-05-08	4.99	6.86	9.49
2		4.95	6.53	9.38
3		4.81	6.60	9.38
4		4.84	6.45	9.31
5		4.81	6.49	9.20
6		4.84	6.42	9.24
7		4.55	6.49	9.20
8		4.99	6.45	9.20
9		4.52	6.42	9.16
10		4.70	6.27	9.20
11		4.48	6.56	9.24
12		4.62	6.49	9.09
13		4.73	6.45	9.13
14		4.55	6.49	9.16
15		4.70	6.42	9.16
16		4.62	6.38	9.13
17		4.59	6.38	9.13
18		4.48	6.42	9.09
19		4.33	6.82	9.02
20		4.44	6.64	8.98
21		4.37	6.53	8.94
22		4.22	6.53	9.02
23		4.29	6.53	9.79
24		4.37	6.49	9.71
25		4.37	6.49	9.57
26		4.44	6.42	9.57
27		4.48	6.64	9.49
28		4.22	6.53	9.46
29		4.15	6.49	9.31
30		4.04	6.49	9.35
	Total	136.49	195.17	278.1
	Maximum	4.99	6.86	9.49
	Minimal	4.04	6.27	8.94
	Average	4.54	6.50	9.27
	Total Buffer pH	120.3	205.8	275.4

In the pH sensor test calibrated with a pH buffer to find the percentage of instrumentation error using equation (1) is:

g. Testing of pH Sensor with pH Buffer 4.01 :

$$\text{Tool Error (100\%)} = \left|\frac{136.49 - 120.3}{120.3}\right| \times 100\% = 0.13\%$$

From the results of the measurements above, the result of the error of the tool on the pH sensor with a pH buffer of 4.01 is 0.13%. To find a comparison of the percentage tool, use equation (2) as follows:

Tool Accuracy (%) = 100% - Tool Error (%)
= 100% - 0.13% = 99.87%

h. Testing of pH Sensor with pH Buffer 6.86

$$\text{Tool Error (100\%)} = \left|\frac{195.17 - 205.8}{205.8}\right| \times 100\% = 0.05\%$$

From the results of the measurements above, it was obtained that the error of the tool on the pH sensor with a pH buffer of 6.68 was 0.05%. To find a comparison of the percentage tool, use equation (2) as follows:

Tool Accuracy (%) = 100% - Tool Error (%)
= 100% - 0.05% = 99.95%

i. Testing of pH Sensor with pH Buffer 9.18

$$\text{Tool Error (100\%)} = \left|\frac{278.1 - 275.4}{275.4}\right| \times 100\% = 0.009\%$$

From the results of the measurements above, the result of the error of the tool on the pH sensor with a pH buffer of 9.18 is 0.009%. To find a comparison of the percentage tool, use equation (2) as follows:

Tool Accuracy (%) = 100% - Tool Error (%)
= 100% - 0.05% = 99.991%

j. Results of Tool Testing at Sea

Testing of seawater temperature and pH measuring devices was carried out in the waters of the Ancol Sea of North Jakarta, where measurements were carried out in the afternoon, 30 data were obtained from temperature and pH sensor measurements. At the same time, measurements were also taken with a thermometer. The test results can be seen in Table 4.

Table 4. Results of Sea Trials

No	Time	Suhu (Celcius)	pH
1	2023-05-08	32.1	9.23
2		32.3	9.69
3		31.7	9.55
4		30.8	9.62
5		31.6	9.37
6		31.6	9.44
7		31.2	9.51
8		31.4	9.24
9		31.5	8.82
10		31.4	8.89
11		31.4	8.96
12		30.9	9.06
13		31.6	9.31
14		31.7	9.24
15		31.7	8.71
16		31.7	8.33
17		31.7	8.33
18		31.8	8.26
19		31.7	8.50
20		32.6	8.61

21		32.1	8.15
22		31.7	8.19
23		32.1	8.26
24		31.8	8.40
25		31.9	8.40
26		32.0	8.43
27		31.6	8.66
28		32.2	7.98
29		31.7	7.84
30		31.7	7.84
	Maximum	32.6	9.69
	Minimum	30.8	7.84
	Average	31.7	8.7

Based on the data obtained from 30 field tests in Ancol Sea Waters, the average water temperature was found to be 31.7°C, with a maximum of 32.6°C and a minimum of 30.8°C. The mean pH value recorded was 8.7, ranging from 7.84 to 9.69. These results are comparable to those reported for Pamayangsari Beach, Tasikmalaya, where water temperatures ranged from 28.5°C to 29.1°C and pH values were between 9.72 and 9.97 [20]. Although the pH and temperature values at Pamayangsari Beach are slightly higher than those in Ancol, both studies demonstrate that this parameter values are within the typical range found in Indonesian marine environments.

Conclusion

Based on the results of the test of the equipment that has been carried out, it can be concluded that the design of a microcontroller-based seawater temperature and pH measuring device can detect water quality by knowing temperature and pH parameters using sensors that are able to work in *real time.* The results of the application of the microcontroller-based seawater temperature and pH measuring device can be said to be able to work well with an average accuracy rate of 99% when compared to thermometers and pH buffers. Thus, microcontroller-based seawater temperature and pH measuring devices can be applied and used in waters.

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