



Prototype Design Monitoring System of A Salt Tunnel Processing Using Heater Based on Smartphone Application

Eka Dina^{1*}, Umi Fadlilah¹

¹ Teknik Elektro, Universitas Muhammadiyah Surakarta, Surakarta, INDONESIA

*Corresponding Author

Abstract:

Indonesia is an archipelago that has a vast ocean with the second-longest coastline in the world. This considerable marine potential affects the variety of livelihoods of people in Indonesia, especially in coastal communities. One of the many livelihoods of coastal communities is being a salt farmer. These farmers still utilize the sun's heat for the evaporation process, so salt production depends on weather factors. If the weather is rainy or cloudy, then the production runs very long or even stops which causes the production yield to decrease. With this condition, it is necessary to have a technology that can help the process of evaporating seawater during cloudy/rainy weather conditions, and even at night farmers can still carry out the process of making salt with a remote monitoring system. Researchers designed and built a prototype for monitoring tunnel salt processing by utilizing a heater for alternative seawater evaporation processes. This requires regular temperature monitoring in the tunnel, so a DS18B20 temperature sensor is used. In addition to the temperature sensor, monitoring the weather around the tunnel with an FC-37 rain sensor is necessary. Monitoring of the salt water concentration is done using a water pH sensor. All sensors' readings are displayed on the I2C 1602 LCD (Liquid Crystal Display) screen. This prototype can be applied directly to a mini tunnel mockup that uses UV plastic material for testing. Monitoring is expected to be real-time and flexible from anywhere, including the heater used must be remotely controlled. Therefore, researchers maximize the use of application-based monitoring systems to improve the effectiveness of the tunnel salt production process.

Keywords:

Application, Heater, Monitoring, Salt Tunnel

1. Introduction

As a maritime country, Indonesia must have tremendous marine potential. The variety of livelihoods of people in Indonesia, especially coastal communities, will be affected by one of these enormous marine potentials. Salt farming is one of the main occupations of coastal communities [1]. As the value of salt imports continues to increase despite the lack of local salt potential, the Indonesian government targets to increase salt production every year. However, due to limited domestic production, the government continues to import large amounts of salt [2]. One of the many places that produce salt is Kampung Garam Kebumen. To increase salt production, various technologies have been used, including geomembrane induction, crystallization houses, and tunnel house systems.

The latest technology is a salt tunnel house system that uses HDPE (High-Density Polyethylene) geomembrane. Tunnel salt products that use HDPE membranes have better quality, such as sodium chloride levels have a cleaner and more hygienic physical appearance than conventional salt products [3]. With this technology, salt farmers can achieve better yields, both in the dry and rainy seasons. In addition, the crystallization process takes place faster on this geomembrane media compared to soil or ceramic media [4].

The rainy season and dry season are the two seasons in Indonesia. Currently, it is difficult to predict the duration of the dry and rainy seasons. [5]. Global warming causes climate change which causes unstable weather [6]. Currently, salt farmers still use solar heat for the evaporation process, so salt production depends on the weather. If it rains or is cloudy, production stops for a very long time, causing salt yields to drop.

This condition requires technology that can help the process of evaporating seawater. With the monitoring system, farmers can continue the process of making salt at night as well. Humans continue to look for solutions to various problems that arise due to the rapid development of technology [7]. Researchers design and build a prototype to track tunnel salt processing using heaters for alternative seawater evaporation processes during cloudy weather. There is a need to monitor the temperature in the tunnel regularly, so a DS18B20 temperature sensor is used. In addition, an FC-37 rain sensor was also required to monitor the weather around the tunnel. A water pH sensor is used to monitor the salt water concentration. All sensor readings be displayed on the I2C 1602 LCD screen.

This prototype test was applied directly to a mini tunnel model using bamboo and UV plastic materials. All this monitoring was expected to be done from anywhere and anytime. The heater that was applied could be controlled remotely. Therefore, a microcontroller was needed that could connect to a Wi-Fi network to send data to a smartphone application. In addition, a microcontroller was also needed that could manage inputs from several sensors. So, the researchers used two microcontrollers in the form of ESP32 and Arduino Uno with RX-TX communication. The researchers wanted to monitor and control the evaporation process in salt manufacturing through a smartphone app-based monitoring system. This allowed for more optimized and efficient production.

2. Method

2.1 Tools and Materials

The design of a prototype monitoring system for tunnel salt processing using a smartphone application-based heater is as follows;

- Hardware includes PCB board, ESP32, Arduino Uno, relay, FC-37 rain sensor, DS18B20 temperature sensor, LCD 1602, water pH sensor, heater, 12v adapter, wire, bamboo, and UV plastic.
- Software used includes Arduino IDE, Fritzing, and Blynk.
- Other supporting systems used for trials in this research are based on the requirements.

2.2 System Design

The tunnel salt processing monitoring system using a smartphone application-based heater had 3 sensors with different functions, including a DS18B20 temperature sensor to read the tunnel temperature, an FC-37 rain sensor that detected the weather around the tunnel, and a water pH sensor to determine the pH content in seawater. The actuator used in this system was only a heater to help provide heat energy to seawater. The microcontrollers used in this system were ESP32 and Arduino Uno,

both connected with RX-TX communication. When the sensor detected the object, the ESP32 sent the output data to the actuator and a notification to the smartphone through display on the Blynk application. The DS18B20 used a 4700 Ω resistor because this sensor required a pull-up resistor connected between the data pin and VCC (Voltage Common Collector). The rain sensor was connected to the ESP32 analog pin so that the sensitivity of the reading could be adjusted as needed. The water pH sensor was connected to the Arduino analog pin, which then sent data using the RX and TX pins from the Arduino to the ESP32. The pH sensor here used a 220v source connected to a relay directly. Besides being displayed on the application, the readings of all sensors could also be seen on the 16 x 2 I2C LCD connected to the SDA and SCL of the ESP32. This system used a stepdown to reduce the voltage from the adapter to the ESP32 and Arduino. The wiring diagram of this system could be seen in Figure 1.

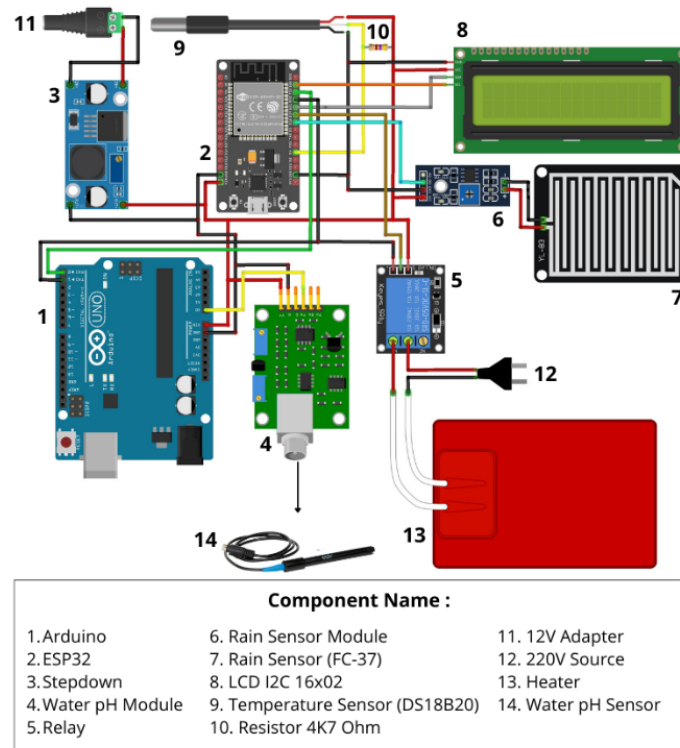


Figure 1: Wiring diagram of the system

Figure 1 shows the wiring diagram of the system, while Figure 2 shows the overall block diagram of the system. It could be seen from the source entering the device that the sensor readings from the salt tunnel were sent to the ESP32 and Arduino Uno. The output of the ESP32 was displayed on the LCD, the Blynk application, and gave commands to the heater.

Based on Figure 2, it is known that the heater itself can be controlled automatically or manually. If the user activates auto control in the application, the heater would turn on automatically at temperatures below 40 °C. Likewise, when the temperature reaches 45 °C, the heater turns off automatically. Conversely, with manual control, users can turn on and off themselves through the application.

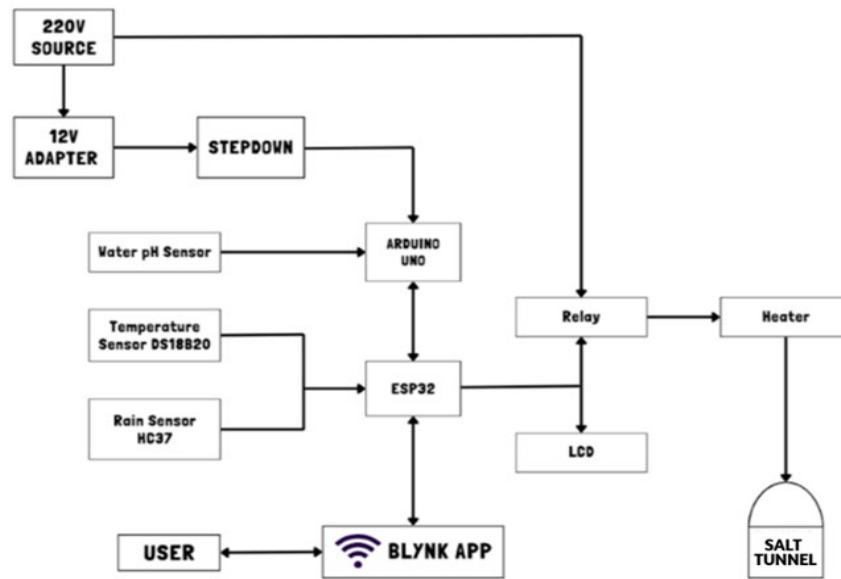


Figure 2: Overall block diagram of the system

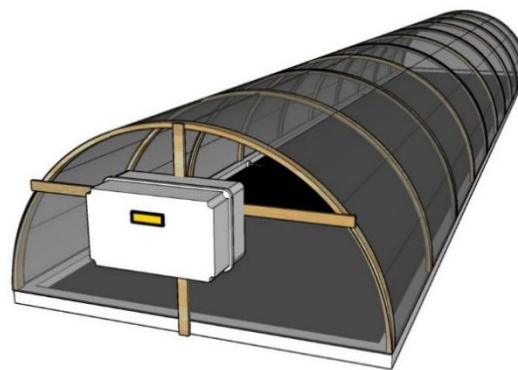


Figure 3: Overall system design

Figure 3 shows the overall design of the prototype that was made. From the tunnel construction, sensor placement to the box system it was made as similar as possible to maximize the efficiency of the results.

2.3 Software Design

The design of software or programs used aims to manage data on monitoring and control systems with microcontrollers. The logic of making the system from reading the condition of the salt tunnel to providing action can be monitored through this smartphone application using C language programming. The flowchart of the program design can be seen in Figure 4 (a) until (c).

The salt tunnel monitoring process starts when the ESP32 gets voltage and connects to the internet and Blynk application. After the ESP32 is ready, the Arduino and all sensors are also active. It can be seen in Figures 4 (a) and 4 (b) that the water pH sensor connected to the Arduino has read the data, then the reading results will be sent to the ESP32 and displayed on the LCD and Blynk application. Likewise with the rain sensor, if it has been exposed to water or reads data, it is immediately displayed on the Blynk and provides notification to the Smartphone when it drizzles or rains. This rain sensor is used to monitor the weather around the tunnel remotely so that it can take actions such as turning on the heater manually through the application. It can be seen in Figures 4 (b) and 4 (c), that there are 2

conditions, namely manual and automatic. The manual condition can be used to activate and deactivate the heater through the application. The auto condition is used to automatically control the heater based on the tunnel temperature. The heater will automatically turn on when the tunnel temperature is ≥ 40 °C with a blue light indicator in the application, and automatically turn off when the tunnel temperature is ≤ 45 °C. In addition, all sensor reading data can be sent via email directly. The ESP32 program for making this system with Arduino IDE software can be seen in Figure 5.

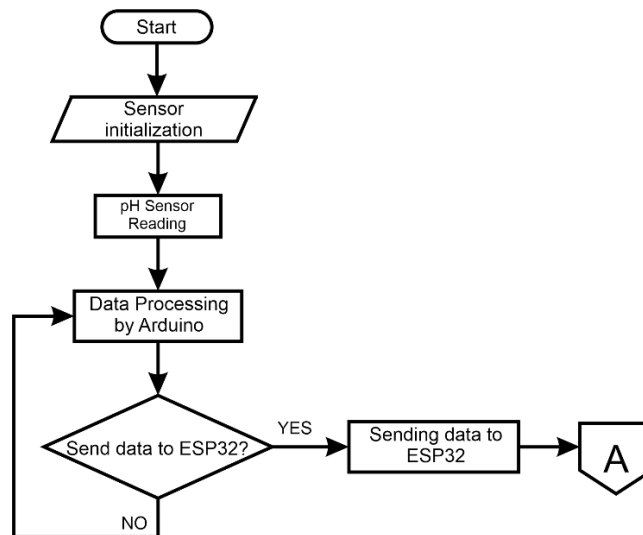


Figure 4 (a): Flowchart of Arduino

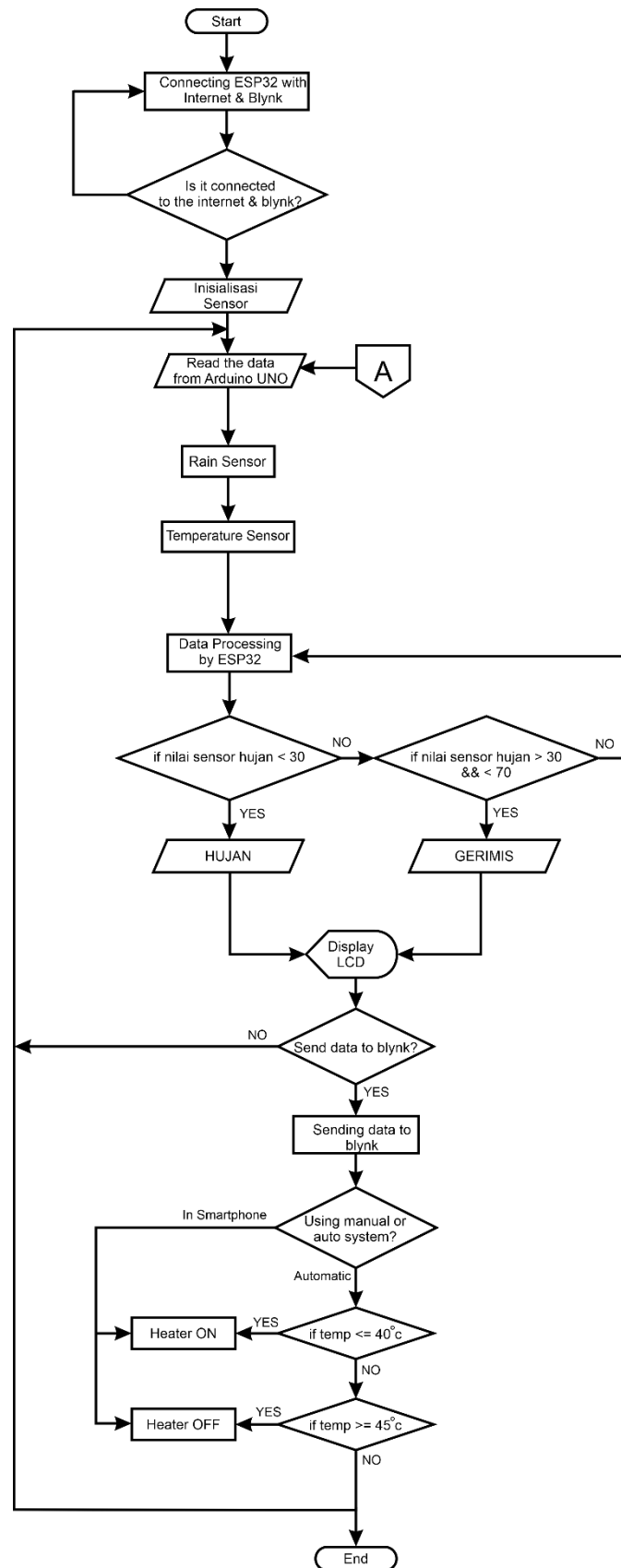


Figure 4 (b): Flowchart of ESP32

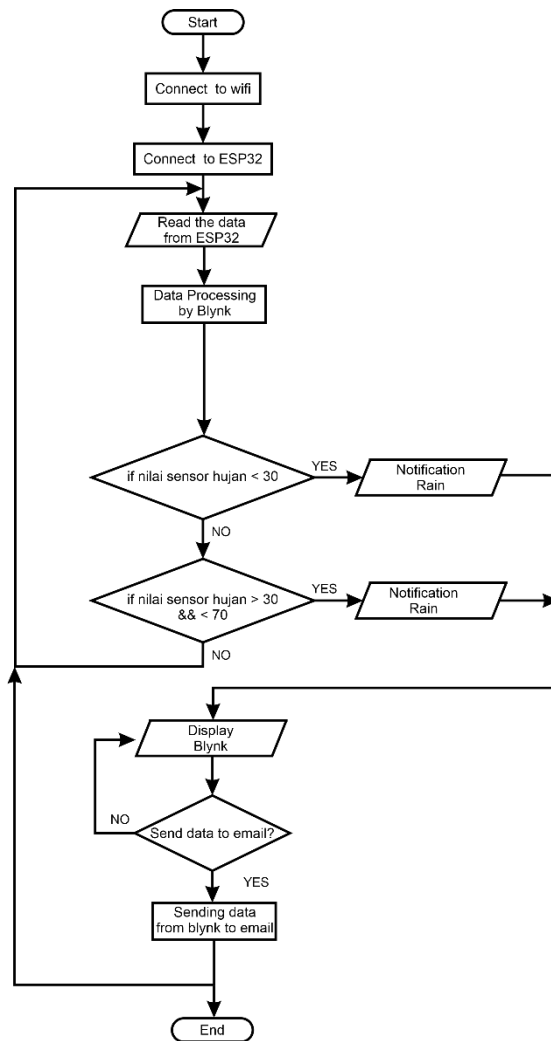


Figure 4 (c): Flowchart of Blynk App

```
PROGRAM_AKHIR
1  // #define BLYNK_PRINT Serial
2  #include <WiFi.h>
3  #include <WiFiClient.h>
4  #include <OneWire.h>
5  #include <BlynkSimpleEsp32.h>
6  #include <OneWire.h>
7  #include <DallasTemperature.h>
8  #include <LiquidCrystal_I2C.h>
9  #include <Wire.h>
10 #include <SoftwareSerial.h>
11 SoftwareSerial FH (16, 17); // RX, TX
12 WidgetLED led1 (V2);
13
14 #define A0_PIN 36
15 #define ONE_WIRE_BUS 4
16 OneWire oneWire(ONE_WIRE_BUS);
17 DallasTemperature sensors(&oneWire);
18 LiquidCrystal_I2C lcd(0x27, 16, 2);
19 float temp;
20 float Po;
21
22 int relay = 19;
23 int mode;
24 int i;
25 int LED;
26
27 char auth[] = "Unt0ekpA2hcB76wKmedijTllkv0c74iL"; // Enter your Auth token
28 char ssid[] = "Fira Elek"; // Enter your WIFI name
29 char pass[] = "ADEK ELEK"; // Enter your WIFI password
30
31 BlynkTimer timer;
32
33 void setup() {
34   Serial.begin(115200);
35   FH.begin(115200);
36   sensors.begin();
37   pinMode(relay, OUTPUT);
38   Blynk.begin(auth, ssid, pass, "iot.serangkota.go.id", 8080);
39   // timer.setInterval(100L, moisture);
40
41   lcd.init();
42
43   // ***LCD***
44   lcd.clear();
45   lcd.setCursor(0, 0);
46   lcd.print("Suhu :");
47   lcd.setCursor(6, 0);
48   lcd.print(temp);
49   if (rainSensor < 38)
50   {
51     lcd.setCursor(0, 1);
52     lcd.print("CUACA HUJAN");
53   }
54   else if (rainSensor > 40 && rainSensor < 70)
55   {
56     lcd.setCursor(0, 1);
57     lcd.print("CUACA GERIMIS");
58   }
59   else if (rainSensor > 75)
60   {
61     lcd.setCursor(0, 1);
62     lcd.print("CUACA CERAH");
63   }
64   delay(3000);
65   lcd.clear();
66   lcd.setCursor(0, 0);
67   lcd.print("Nilai Ph:");
68   lcd.setCursor(10, 0);
69   lcd.print(Po);
70   delay(1000);
71
72   Blynk.run();
73   timer.run();
74 }
```

Figure 5: Program on Arduino IDE

3. Results and Discussion

This section describes the research study's results in the final project.

3.1 Results of the Design of Tunnel Salt Processing Monitoring System Using Heater Based on Smartphone Application.

The hardware of this system is made using PVC plastic material with a size of 22cm x 15cm x 12cm for the system box and bamboo material along with UV plastic for the salt tunnel. Details of the prototype system can be seen in Figure 6.

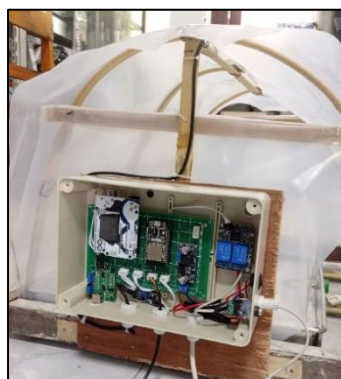


Figure 6 (a): Components of the system



Figure 6 (b): Inside and outside view of prototype

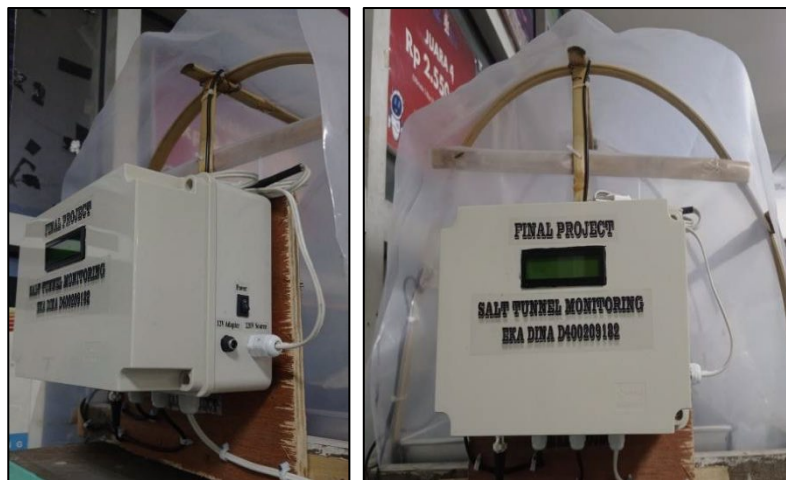


Figure 6 (c): Front and side view of the box on the prototype

The prototype in Figure 6 (a) shows that there are main components such as the Arduino, ESP32, relays, and stepdown inside the box. On the other hand, Figure 6 (b) shows the inside and outside of the tunnel physical framework, where there is a baking sheet, DS18B20 temperature sensor, rain sensor, pH sensor, and heater output. In Figure 6 (c), there is a power button and cables to the power source (220v and 12v), and the front of the box has an LCD that will display the sensor readings. All cables are neatly organized and wrapped in a baked sleeve to protect them from water. The LCD and rain sensor are outside so they can work according to their function.

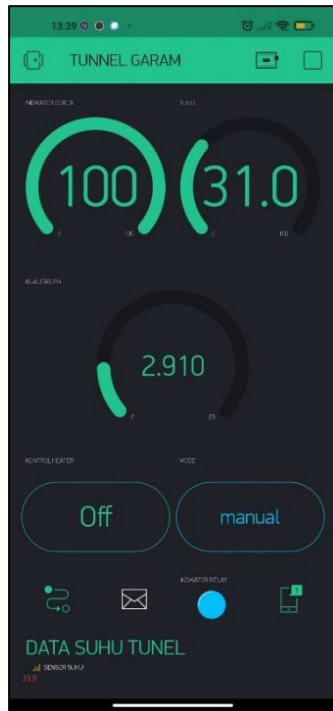


Figure 7 (a): Smartphone app view



Figure 7 (b): Heater auto control display



Figure 7 (c): Smartphone app view of data result for send email

This smartphone application is intended for users to monitor and control the heater in the salt tunnel. The display can be seen in Figure 7 (a), which consists of temperature, rain, and water pH sensor data. Under the sensor data display on the right side there is a button manual or auto heater controller, and on the left side is the heater indicator on or off. If the system is in auto condition, the light indicator will turn on and off automatically, the display can be seen in Figure 7 (b). Meanwhile, Figure 7 (c) is the

reading data that is stored and can be sent to the user's email in the form of a CSV file and the data can be reported in real-time.

3.2 Prototype Testing Results

Prototype testing is carried out under direct sunlight and using seawater. After the seawater is put into the pool, the prototype is connected to the AC source. When the device is turned on, the system works according to the program that has been set. The temperature sensor reads the temperature conditions in the tunnel. If the user chooses auto control, the temperature gives a command to the heater to turn on when the temperature is below 40 °C and stop automatically when the temperature reaches 45 °C. Conversely, if the user chooses manual control, the heater can be turned on and off via smartphone. The rain sensor detects the weather around the tunnel, if exposed to water droplets it sends a notification to the user's smartphone. The pH sensor reads the pH of the seawater. Naturally, seawater has a slightly alkaline pH value, which is around 8.1 to 8.4. However, due to increased Co2 emissions from human activities, seawater is becoming more acidic, thus lowering the pH value of seawater. Changes in the pH of seawater can affect the lives of marine organisms, especially those that undergo the calcification process, such as corals, shellfish, and macroalgae. Because the quality of salt based on SNI (Indonesia National Standard) has a minimum NaCl (Natrium Chloride) content of 95%, Sulfate, Magnesium, and Calcium a maximum of 2%, and other impurities (mud and sand) a maximum of 1% (dry weight), and a maximum moisture content of 7%.



Figure 8 (a): Prototype testing process during the day



Figure 8 (b): Prototype testing process at night

This salt tunnel monitoring and control system is a system needed in salt farming. This research was made to help salt farmers monitor the temperature, pH content, and weather around the tunnel and control the heater from a close or far distance. This was done because of suggestions from farmers when interviewed, that the process of making salt is often hampered and even decreases when the rainy season arrives. So this tool will be useful in the real-time monitoring process to take other actions when it rains. This research has the advantage of being equipped with heater control, so production can also be done at night. Prototype testing was carried out during the day as shown in Figure 8 (a), and at night as shown in Figure 8 (b). Some sensors require calibration to work properly. The following are some test results for each sensor.

3.2.1 DS18B20 Temperature Sensor Testing

Temperature sensor testing is carried out directly on the prototype during the day and night using a comparison of temperature meter measuring instruments which will determine the average error.



Figure 9: Temperature sensor testing

Figure 9 is a sample test between the temperature sensor displayed in the application and the result from the measuring instrument. As explained earlier, if the tunnel temperature is below 40°C, the heater will turn on automatically and turn off when the temperature reaches 45°C. Likewise, when the condition is manual, the user can immediately take action if desired.

$$\text{Error} = \frac{X - X_i}{X} \times 100\% \quad \text{Eq. 1}$$

The equation above is the percentage error formula from the temperature sensor test carried out, according to the following information.

X = Tunnel Water Temperature Thermometer Value (°C)

X_i = Tunnel Water Temperature Sensor Value (°C)

Meanwhile, to determine the average, the following formula applies.

$$\text{Average} = \frac{Y}{Z} \quad \text{Eq. 2}$$

Description:

Y = Sum of All Value Difference (sum of number 1 until 8)

Z = The Amount of Data Difference

Table 1: Temperature sensor test result data

No.	Thermometer Tunnel Water Temperature (°C)	Tunnel Water Temperature Sensor (°C)	Difference	Error (%)
1	29	29.75	0.75	2.586206897
2	30	30	0	0
3	31	31	0	0
4	35	35.7	0.7	2
5	40	40	0	0
6	42	42	0	0
7	44	44	0	0
8	45	45	0	0
Average			0.18125	0.5732758621

The error and average formula can be calculated using Formulas 1 and 2. Table 1 shows the test results between the temperature sensor and the measuring instrument which has an average difference of 0.18125 (from subtracting the values of the thermometer and temperature sensor) and an average error of 0.57327. It can be said that the temperature sensor has good accuracy.

3.2.2 FC-37 Rain Sensor Testing

Testing the rain sensor during the day is done by dripping water onto the sensor. But at night the testing is using rainwater.

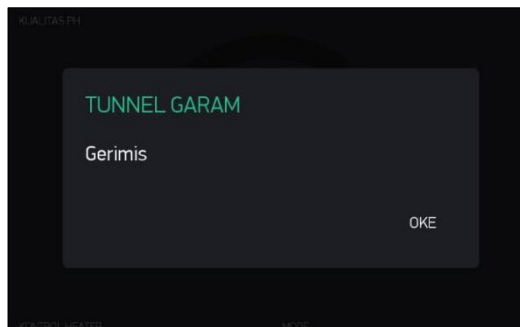


Figure 10 (a): Testing of drizzle

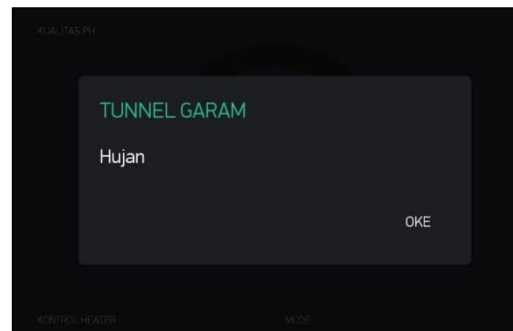


Figure 10 (b): Testing of rain

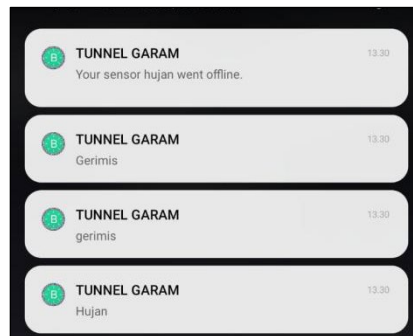


Figure 10 (c): Testing of notification

The rain sensor reading results are sent as a notification on the smartphone application. Figure 10 (a) is a notification on the application when it drizzles and Figure 10 (b) notification when it rains. All notifications still come in, even if you do not open the application, as in Figure 10 (c). Another notification is the rain sensor is not connected to the system or the internet.

Table 2: Rain sensor test result data

No.	Rain Sensor	Notifications
1	8	Rain
2	34.5	Rain
3	44.1	Drizzle
4	59	Drizzle
5	63	Drizzle

6	77.5	Sunny
7	97.5	Sunny
8	100	Sunny

Table 2 shows the results of testing the rain sensor with the analog value read. Several times it reads rain because the program has been set. If the rain sensor reads below 38 °C, it will send a rain notification, but if value is between 40 to 70 it will send a drizzle notification, and when it reads above 75 it will send a sunny notification. For example, when the first test result is 8, the notification sent is rain, and so on.

3.2.3 Water pH Sensor Testing

Testing the pH sensor is done using sampling which have been compare the pH sensor with the pH (Potential of Hydrogen) meter. This sensor has its own calculation method, namely the calibration of the pH sensor according to the formula for the acidity level that has been determined in the form of pH 4 and pH 7 of the powder. Formulas 3 and 4 are included in the Arduino program.

$$\text{pH step} = \frac{(\text{pH 4 Voltage} - \text{pH 7 Voltage})}{\text{pH 4} - \text{pH 7}} \quad \text{Eq. 3}$$

$$\text{pH step} = \frac{(3.140 - 2.617)}{3}$$

Then the result of the pH step is entered into the formula:

$$\text{Po} = 7.00 + \left(\frac{(\text{pH 7} - \text{pH Voltage})}{\text{pH step}} \right) \quad \text{Eq. 4}$$

$$\text{Po} = 7.00 + \left(\frac{((2.617 - \text{pH Voltage}))}{0.15} \right)$$

Description:

pH step : Formula for taking voltage data from pH4 and pH7 solutions.

Po : pH Output.

pH Voltage : $\frac{5}{1024.0} \times$ Readings from analog sensor

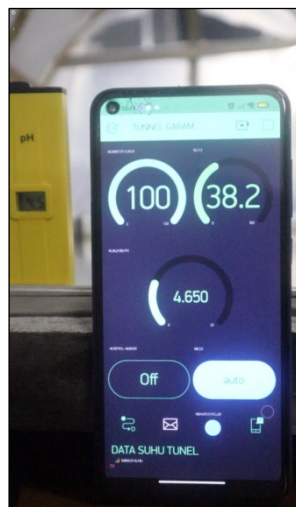


Figure 11: Water pH sensor testing

Figure 11 is one sample of the pH sensor reading results with a pH meter. It can be seen that the result of the pH sensor is 4.650 while the pH meter obtained 4.5. The conclusion of the difference and also the error between the two are shown in Table 3.

Table 3: Water pH sensor test result data

No.	pH Meter (pH)	Water pH Sensor (pH)	Difference	Error (%)
1	2.7	2.71	0.01	0.3703703704
2	2.9	3.15	0.25	8.620689655
3	3.3	3.4	0.1	3.03030303
4	3.5	3.5	0	0
5	3.6	3.6	0	0
6	3.8	3.8	0	0
7	4.5	4.65	0.15	3.333333333
8	5.7	6	0.3	5.263157895
Average			0.10125	2.577231785

The formula for finding the difference and error is still the same as the formula for error and average. Table 3 shows 8 test results with a difference between the pH meter and the pH sensor of 0.1 and an error of 2.5. It can be said that the pH sensor has pretty good accuracy.

3.2.4 Heater Actuator Testing

This heater test is carried out in two conditions, which in manual and automatic. Auto conditions are based on the tunnel temperature read on the temperature sensor. While the manual condition is based on the user's wishes.

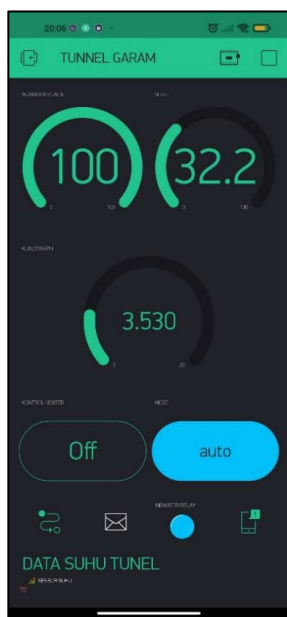


Figure 12 (a): Heater actuator auto testing

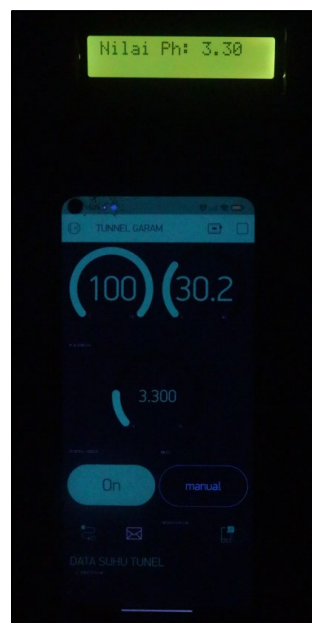


Figure 12 (b): Heater actuator manual testing

Figure 12 (a) shows the auto condition where the heater is on, and Figure 12 (b) is the manual condition where the heater is on. Both tests were conducted during the day and night. This heater is one of the main advantages of this system, because the process of making salt can still be done when it rains or at night.

Table 4: Heater actuator test result data

Manual	Auto	Conditions
On	On	Completed
Off	Off	Completed

The test results are summarized in Table 4, where the manual conditions when the heater is on and off are met. Likewise, when the auto condition, the heater on and off automatically has also been fulfilled and following the condition of the temperature sensor reading.

3.2.5 Overall Test Results Along with the Application

Tests of the entire system carried out simultaneously during the day can be seen in Table 5 and at night in Table 6. The test results for sending data from the system to the application are also listed in Table 7.

Table 5: Testing the device during the day

Temperature Sensor	Rain Sensor	pH Sensor	Relay (automatic)	Relay (Manual)	Weather Descriptions
29	8	2.49	Off	On	Rain
30	34.5	2.88	On	Off	Rain
33	44.1	3.36	Off	On	Drizzle
37	59	3.47	On	Off	Drizzle
40	63	3.7	Off	On	Drizzle
42	77.5	4	On	Off	Sunny
44	97.5	4.42	Off	On	Sunny
45	100	4.69	On	Off	Sunny

Table 5 is a summary of the overall test during the day, it can be seen that the temperature sensor reading does not affect the relay condition if the user uses the manual condition. Vice versa, if the user uses the auto condition then the manual condition is not active. The rain sensor here have been affect the weather information on the LCD and application notifications.

Table 6: Testing the device during the night

Temperature Sensor	Rain Sensor	pH Sensor	Relay (automatic)	Relay (Manual)	Weather Descriptions
29.75	7.3	2.71	On	Off	Rain
30	34.5	3.15	Off	On	Rain
31	37.3	3.4	On	Off	Rain
35.7	39	3.5	Off	On	Rain
41	44.1	3.6	On	Off	Drizzle
42	100	3.8	Off	On	Sunny
44	100	4	On	Off	Sunny
45	100	6	Off	On	Sunny

Table 6 is a summary of the overall test at night. The test is still the same as during the day, but at night the system can be maximized to turn on the heater so that the salt production process continues, so that there is no slack in the salt harvest (stay on target harvest).

Table 7: Data delay delivery from system to application

No.	Range (Km)	Delay System to Application (seconds)
1	0.001	0
2	0.005	1
3	0.01	1
4	0.03	2
5	0.05	2
6	0.1	3
7	0.5	3
8	1	4

Finally, Table 7 is the result of testing the data transmission from the system to the application with several ranges in kilometers. The results obtained when the application is near the system then there is no delay, but when it is at 5-10 meters from the system there is a 1 second delivery delay. When the distance is at 30-50 meters there is a delay of 2 seconds, a distance of 100-500 meters there is a delay of about 3 seconds, and when tried at a distance of 1 kilometer there is a delay of about 4 seconds.

3.2.6 Quantity of Salt Production

In this experiment, the seawater samples of 1000 ml, 7000 ml, and 10000 ml were used. Generally, 1000 ml of seawater produces 40 grams of salt, 7000 ml of seawater produces 280 grams of salt, and 10000 ml of seawater produces 400 grams of salt. The analysis conducted for this experiment, the less seawater used, the lower amount of salt crystallization. This is presumably, because the salt content in the seawater used is also small. The experiment suggests that the amount of salt obtained from seawater crystallization is directly proportional to the volume of seawater used, assuming constant salinity conditions. Factors such as salinity, evaporation rate, and experimental error can influence the final salt yield. To obtain more accurate and consistent results, it is essential to control these variables and use standardized experimental procedures.

3.2.7 Comparison of Seawater to Salt Time

Tunnel salt production takes 1 week to produce 1 ton of consumption salt and SPA (Salus Per Aquam) salt during the dry season, with a tunnel area of 4x21x0.5 meters. This production generates an income of around 25-30 million rupiah per month. The number of tunnels on an area of 1 hectare is 6 pairs, or 36 tunnels. Meanwhile, salt production using a heater, with a prototype area of 0.6x0.4x0.006 meters, can produce 400 grams in 8 hours during the dry season and 13 hours in the rainy season. However, once the dry season ends, the original tunnel salt production method cannot be done optimally because the production process takes longer. The use of a heater remains beneficial during the rainy season, as it allows salt production to continue. Additionally, when farmers wish to produce salt at night, the heater can still support production. This approach can help salt producers enhance their overall profitability and resilience to changing climatic conditions.

3.2.8 Comparison of Salt Production Costs

This experiment was conducted to calculate the power consumption of the 150-watt heater, in order to determine the cost incurred during each salt production cycle with this prototype. The electricity cost is based on the price for a 900 VA subsidized rate. The results of the experiment showed that the cost of using the heater is IDR 202.8 per hour, and in 8 hours, it produces only 400 grams of salt. To produce 1 kg of salt, it takes 2.5 times longer, so 8 hours x 2.5 = 20 hours. Therefore, the cost needed to produce 1 kg of salt is IDR 4,056.

In comparison, the price per kilogram of salt from tunnel salt farmers ranges from IDR 7,000 to IDR 8,000. From the experiment, it can be concluded that the cost of salt produced by the prototype is cheaper than the original tunnel salt, but this does not yet account for the overall power requirements of the equipment. Additionally, tunnel salt production can only meet the target yields during the dry season. Therefore, this experiment remains feasible for use in the rainy season to help meet the salt demand in Indonesia.

4. Conclusion

This prototype monitoring system was tested on each sensor and actuator with seawater during both day and night. The temperature sensor and pH sensor performed well, as the readings were similar to those of the measuring instruments, with only a very small average error. The rain sensor also showed good accuracy in reading analog values, ensuring that notifications sent to the application were accurate and without delay. The heater was tested based on temperature and weather, as the system has two modes: auto and manual. In auto mode, the heater automatically turns on and off when the temperature is below 40°C and above 45°C. In manual mode, the user can turn the heater on and off according to the situation. This is one of the system's advantages, as it can assist with production even during rain or at night. Besides enabling production at any time, the use of this system greatly facilitates salt farmers.

Based on the experiments conducted, this prototype can replace the role of the sun, although additional operational costs are incurred due to the use of electricity for the heater. Tunnel salt production over 1 week (7 days) can yield approximately 1 ton during the dry season, while this prototype produces 8.4 kg, with a selling price of IDR 4,056 per kg, considering the size difference between the prototype tunnel and the original tunnel. These calculations make the system more effective.

If implemented, controls in the form of buttons or switches around the tunnel could be added to make it easier for salt farmers to operate the system. Further research could explore using solar panels as an energy source to improve efficiency and reduce electricity costs. If the electrical energy source is

confirmed to be safe, it may be possible to increase the number of heaters or use heaters with higher heat energy capacity to make the production process more effective. The system could also integrate internet connectivity by installing modems or routers around the salt tunnel. The use of the application could be expanded into a web-based platform or mobile app that could be installed via the Google Play Store.

References

- [1] KKP. (2022). Produksi Garam Tahun 2020. *Retrieved from* <https://kkp.go.id/brsdm/sosek/artikel/41044-produksi-garam-tahun-2020>.
- [2] Maulana, K. D., Jamil, M. M. M., Putra, P. E. M., Rahmawati, R., & Rohmawati, B. (2017). Peningkatan Kualitas Garam Bledug Kuwu Melalui Proses Rekrystalisasi dengan Pengikat Pengotor CaO, Ba (OH) 2, dan (NH4) 2CO3. *Journal of Creativity Student*, 2(1), 42-46.
- [3] Rusiyanto, R., Soesilowati, E., & Jumaeri, J. (2013). Penguatan industri garam nasional melalui perbaikan teknologi budidaya dan diversifikasi produk. *Saintekno: Jurnal Sains dan Teknologi*, 11(2).
- [4] Arwiyah, Zainuri, M., & Efendy, M. (2015). Studi Kandungan Nacl Di Dalam Air Baku Dan Garam Yang Dihasilkan Serta Produktivitas Lahan Garam Menggunakan Media Meja Garam Yang Berbeda. *Jurnal Kelautan*, 8(1), 1-9.
- [5] Nofianto, Siti, & Sulhan. (2022). Penelitian tentang Prediksi Hujan selama Musim Penghujan di Indonesia. *Jurnal Cuaca Tropis*, 10(2), 50-65.
- [6] Sanaris, Ahmad, & Suharjo, Bambang. (2020). Dampak Perubahan Iklim Akibat Pemanasan Global di Indonesia. *Jurnal Lingkungan dan Sumber Daya Alam*, 5(1), 25-35.
- [7] Nasution, Ria, Marpaung, Simbolon, & Nasution, Ari. (2023). Perkembangan Teknologi Elektronika dalam Menyelesaikan Masalah Sehari-hari. *Jurnal Teknologi Modern*, 15(3), 80-95.
- [8] R. A. Ivory, N. Kholis, Nurhayati, and F. Baskoro, "Review Penggunaan Sensor Suhu Terhadap Respon Pembacaan Skala Pada Inkubator Bayi," *J. Tek. Elektro*, vol. 10, no. 1, pp. 185–194, 2021.