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Automatic Water Desalination Device using Sugeno Fuzzy Logic (Case Study: Tangkil Coast)

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***Abstract*:**
Water desalination is the process of making fresh seawater or the process of making fresh water from salt water. This study uses a thermal desalination process because the salt content produced is less than the results from membrane desalination. This fuzzy method also has several variations in its application. The fuzzy Sugeno method used in this study differs from other methods, that is, with this method the results are in the form of constants or linear equations so that they can automate the desalination process. Tangkil Island is used as the object in this case study because it is a center for family tourism but has difficult access to fresh water. This study tested the results of desalination water by using a salinity measuring instrument with the type of salinity-615 as the standard for reading salt levels. The comparison results have an error value of above 50% due to the difference in the reading digits of the salinity-615 tool, which only has a value of 1 digit behind the comma, so that the results compared with the salt level sensor (embedded), which can read 3 digits behind the comma, have a high error percentage. The results of the tests carried out using Matlab with the actual conditions at the temperature, humidity, and water level observed that the desalination process runs automatically. From the results of these tests, there are very large differences in the calculation of the evaporation rate. The temperature and humidity factors can change at any time, which causes very large differences from the calculation results. In line with the increase in temperature and decrease in humidity, the evaporation process will be faster but will experience a slowdown in the evaporation process if the opposite occurs.

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1. INTRODUCTION

Indonesia is an archipelagic country that has a coastline that reaches 81,000 km [1]. This statement proves that Indonesia has a high seawater capacity. Computer technology is automatically needed to make it easier to manage the management of Indonesia's existing resources [2].

The dependence of the community on marine products is also very large. It cannot be denied that the difficulty in using fresh water for coastal communities is a troublesome problem for the local population. This condition is in line with the results of interviews that the author conducted with the residents of Tangkil Island, which has an area of about 12 hectares, so that they often lack fresh water sources to meet their daily needs. So far, their freshwater needs are imported from the other side of the island. The need for the use of fuel oil is also getting higher to meet the needs of water imported to the opposite island with the use of fuel, as much as 15 liters a day.

Against this backdrop, the author took the initiative to try to provide fresh water to residents by means of a computerized desalination process with an embedded system. Utilizing large amounts of salt water into fresh water, this process will save energy and time as well as the costs incurred compared to the process of transporting from the other side of the island.

This research will use an embedded system. An embedded system is a computer-based system that is programmed for a specific task and embedded as a part in a computer system or in a piece of equipment and sometimes does not show that the equipment is controlled by a computer [3]. Referring to the understanding of embedded systems, the author wants to do research using Arduino as a microcontroller to monitor all activities of automatic water desalination devices.

The embedded system developed must have a standard or basis used for classifying the freshwater. Referring to the book by Paul Montagna, which contains water salinity values for fresh water ranging from 0–0.5 ppt, brackish water ranging from 0.5–30 ppt (brackish water salinity), and marine water salinity >30 ppt [4]. Important data and parameters are used for research [5][6]. The theory in the results of this study will be used as a basis for measuring salt levels in water for daily use.

The research developed by [7] uses the same concept in developing the tool. A tool that is designed to perform desalination automatically but uses the Computational Fluid Dynamics method where the process that is focused on by the maker is to concentrate solar heat to be channeled throughout the field, which will heat the seawater [7]. In previous research, the author has a reference that is used as a comparison with the tools developed by the author. The tool is called Reosquido, which is a tool that can perform an automatic water desalination process using the Arduino Mega microcontroller by heating a heater so that the evaporation process occurs in the tool that was made [8]. Previous research that has a relationship with seawater desalination has its own uniqueness, as the tool made by [9] has two ways in the water desalination process. The other developed systems that focus on the physical process were developed by [10] using the principle of capacitive deionization (Cdi) based on activated carbon. A system created by [11] has the aim of monitoring the desalination process via the web, which is controlled directly using a smartphone so that data can be monitored in real time.

Based on the problems described above and referring to previous research, the author wants to make a system program embedded in a device that functions as a monitor to manage salt water or brackish water from salt water intake to water distillation data displayed on the computer. These stages are controlled by a microcontroller that has an integrated program embedded in it. The method used for the application of the system to be designed is fuzzy logic, where the determination of variables that influence the monitoring of the automatic water desalination process must be precise. Various types of fuzzy logic also have their own differences depending on the use and cases applied by the developer. Here the author uses the Sugeno method, which can model the inference stage in the IF-THEN form, whose output is not in fuzzy but constant form [12].

2. METHODS

2.1 Research Flow

In this study, there are several steps that must be taken to build an expert system and vital sign test kit for the cat. The steps to realize these applications and tools can be seen in the following Figure 1.

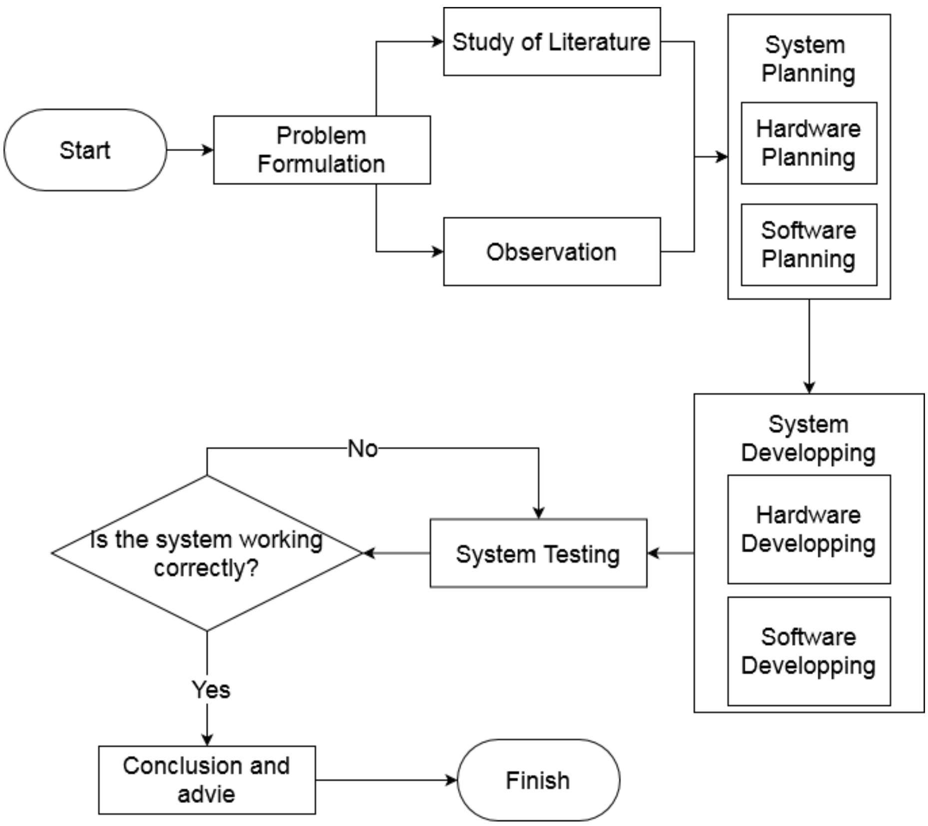


Figure 1. Research Flow

1. Literature Study and Observation
   At this stage, literature to enrich research materials and theoretical basis to be used in research design such as fuzzy method [13][14]. Desalination method of even at the same time the observation goes for the reality takes place in Tangkil coast.
2. System Planning

After making the theoretical basis, the next stage is the design. It consists of two designs, namely the system design, and the test design. The system design contains hardware design, Sugeno fuzzy design and software design used for system development. The test design contains hardware test design, and fuzzy logic design.

3. System Developing
   At this stage, the implementation and completion of the systems and tools contained in the approved system and tool design documents are carried out. The stages of software development need to be carried out by adjusting the functional requirements of the system [15][16].
4. Testing
   At this stage, testing was carried out to check if the system was working correctly or not. The testing for the salinity meter uses a tool called salinity-615. For software testing, MATLAB is used to compare the fuzzy output with the system for the automation.

2.2 System Design

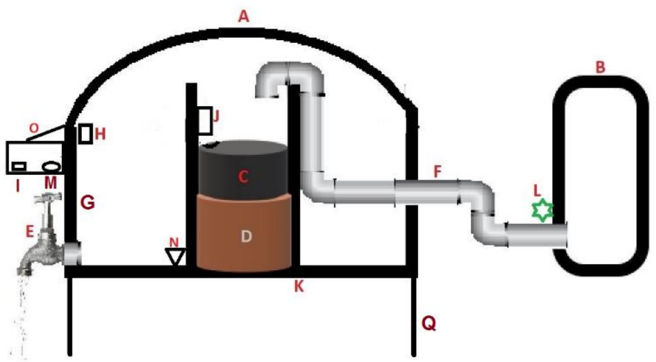
The system designed is an embedded system that uses the Arduino Mega as its microcontroller. The system can carry out the desalination process automatically by accommodating all the salt water which will be processed into fresh water. This process can be carried out systematically if the sensor reads the surrounding conditions such as temperature, humidity, and water limit, which are used as parameters for the process of moving water from the storage container to the heating container.

The most important role in moving the water is in the relay that turns the mini 3V water pump on and off. The sensors used in this process are the DHT11 sensor for humidity and temperature, and the rain sensor, which is used as the water level limit. Then the evaporation process occurs in a heating container that absorbs heat from the sun. After the evaporation process occurs, the water droplets that fall will be checked by the salt level sensor. All outputs from sensors that check every parameter in the desalination process will be displayed on a 2x16 LCD on the outer wall of this tool. Tools and sensors used in the design can be seen in Table 1. The side view of the design of systems can be seen Figure 2.

Table 1. Tools and Sensors

No.	Tool Name	Function
1	Arduino Mega	as a tool that controls all system activities, from integrating with sensors to embedding fuzzy logic
2	Transparent cover	used to capture water vapor and curved design so that water vapor can flow down to the freshwater container
3	Container for holding salt water	used for holding salt water to be processed by the system

No.	Tool Name	Function
4	Black marble	dark material that is used for absorbing the sun's heat to speed up the evaporation process
5	DHT11	sensor used to check the humidity and temperature around the device to provide output to the relay to turn the mini water pump on and off
6	FC-37 Sensor	sensor to detect the presence of water or not at a specified height
7	Fresh water container	a water reservoir after going through the desalination process
8	Mini water pump	used for draining salt water located in the salt water storage container to the heating container
9	relay	used for digital switch on mini water pump based on DHT11 sensor output and rain sensor
10	Salt level sensor	used for checking the salt content in water that has gone through the evaporation process
11	LCD 2x16	used for displaying the output for the state of temperature, humidity and salt content.
12	Water Sensor HW-038	used for adjusting the water level in clean water containers so that they are not exposed to other components.



A= Transparent cover
B= Container for salt water
C= Marble is black
D= Seat
E= Water faucet
F= Hose or pipe
G= Bucket
H=Temperature and humidity sensor
I= Arduino Mega
J= Rain sensor
K= Fresh water container
L= Mini water pump 3V
M= Relay
N= Salt level sensor
O= LCD 2x16
P=HW-038 water sensor
Q= Support wood

Figure 2. Side View of System Design

The following is a hardware implementation design and its wiring scheme can be seen in Figure 3. The Arduino Mega 2506, which has 54 input/output pins, is connected to the breadboard with jumper cables on the positive and negative poles for voltage distribution (5V) and ground. There are four main sensors used for state readings, namely the hw-038 sensor, often known as the water sensor, the fc-37 sensor, often known as the rain sensor, the DHT11 sensor, often known as the humidity and temperature sensor, and the salt level sensor.

The hw-038 sensor is connected with a jumper cable to the Arduino board with analog pin A1 for reading the state of the water level in the freshwater container. The fc-37 sensor is connected with a jumper cable to the Arduino board with digital pin D4 for reading the presence or absence of water in the heating container. The DHT11 sensor is connected with a jumper cable to the Arduino board with digital pin D2 for reading the state of temperature and humidity inside the device. The salt level sensor is connected with a jumper cable to the Arduino board with analog pin A0 to check the salt content of the water that has gone through the evaporation process.

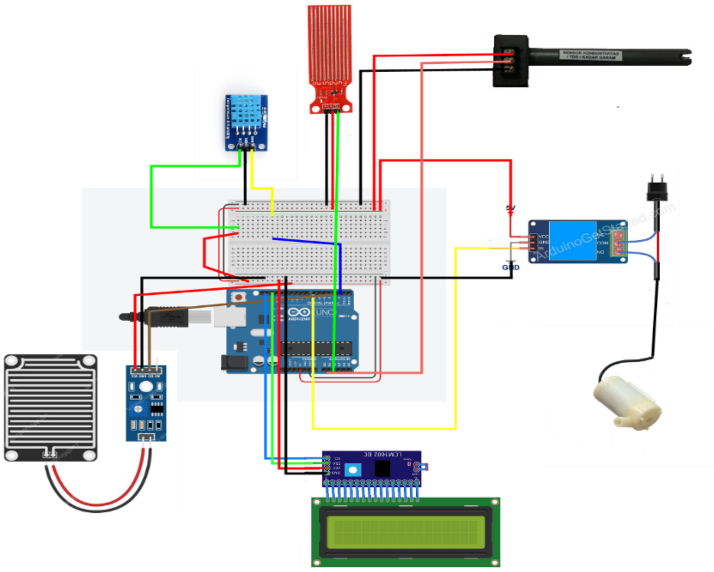


Figure 3. Hardware and Wiring Schema Diagram

After checking the state of the fc-37 sensor, hw-038 sensor, and DHT11 sensor, all the results of the check are carried out by a fuzzy calculation process which will provide an output for the relay, which is connected with a jumper cable to the Arduino board with digital pin D2 to turn the pump on and off to automate the water desalination process. After the evaporation process occurs, the water that has evaporated will go directly to the freshwater container below, where there is a salt level sensor connected by a jumper cable to the Arduino board with analog pin A0. So all inputs on the sensor that have checked the state of the device will display a 2x16 LCD, which is combined with the i2c module for easy wiring. This 2x16 i2c LCD is connected with a jumper cable to the Arduino board at the SCL and SDA pins. The display results issued by the 2x16 i2c LCD are readings of the state of temperature, humidity, and the type of water that has evaporated, whether it is fresh, brackish, or marine.

2.3 Fuzzy Logic Design

The design of the Sugeno method of fuzzy logic has four stages to identify the input. These stages include:

a. Fuzzification

In the fuzzification stage, it changes the input data in the form of temperature, humidity, and HIGH or LOW of the FC-37 sensor from a crisp form to a linguistic variable form. The modified data can be seen in Table 2.

Table 2. Fuzzification

Parameter Values		Fuzzy Variable
Temperature (S)	0-18 ˚C	Cold
	18-28 ˚C	Normal
	28-50 ˚C	Hot
Humidity (K)	20-60%	Dry
	60-89%	Humid
	89-100%	Wet
FC-37 Sensor (AIR)	0	Off
	1	On

b. The Stages of Forming the Rule Base

The stage of forming the fuzzy base rule is the formation of a rule that is used to process fuzzy data. There are three input variables in the form of temperature, humidity, and the HIGH or LOW of the FC-37 sensor, which has three variables for temperature and humidity, but two variables for the HIGH or LOW state of the sensor FC-37. Then there are eighteen fuzzy logic rule bases, including:

1. Cold Temperature, Dry Humidity, and FC-37 Sensor Off
2. Cold Temperature, Humidity, and FC-37 Sensor Off
3. Cold Temperature, Wet Humidity, and FC-37 Sensor Off
4. Normal Temperature, Dry Humidity, and FC-37 Sensor Off
5. Normal Temperature, Humidity and FC-37 Sensor Off
6. Normal Temperature, Wet Humidity, and FC-37 Sensor Off
7. Hot Temperature, Dry Humidity, and FC-37 Sensor Off
8. Hot Temperature, Humidity and FC-37 Sensor Off
9. Hot Temperature, Wet Humidity and FC-37 Sensor Off
10. Cold Temperature, Dry Humidity and FC-37 Sensor On
11. Cold Temperature, Humidity and FC-37 Sensor On
12. Cold Temperature, Wet Humidity and FC-37 Sensor On
13. Normal Temperature, Dry Humidity and FC-37 Sensor On
14. Normal Temperature, Humidity and FC-37 Sensor On
15. Normal Temperature, Wet Humidity and FC-37 Sensor On
16. Hot Temperature, Dry Humidity and FC-37 Sensor On
17. Hot Temperature, Humidity and FC-37 Sensor On
18. Hot Temperature, Wet Humidity and FC-37 Sensor On

c. Inference Machine

The inference stage is a rule to produce the output of each rule. There are 2 fuzzy logic outputs with values 0 and 1. The output results in the mini water pump actuation process are Pump On, and Pump Off. This results in eighteen rules consisting of three entries. The results of the elaboration can be seen from the explanation of the following rules, namely:

1. If Cold Temperature, Dry Humidity, and the FC-37 Sensor Are Off, the Pump is Off

2. If the Temperature is Cold, Humidity, and the FC-37 Sensor is Off, the Pump is Off
3. If Cold Temperature, Wet Humidity, and the FC-37 Sensor Are Off, the Pump is Off
4. If Normal Temperature, Dry Humidity, and FC-37 Sensor Are Off, the Pump is Off
5. If Normal Temperature, Humidity, and FC-37 Sensor Are Off, the Pump is Off
6. If Normal Temperature, Wet Humidity, and FC-37 Sensor Are Off, the Pump is Off
7. If the Hot Temperature, Dry Humidity, and FC-37 Sensor Are Off, the Pump is Off
8. If the Hot Temperature, Humidity, and FC-37 Sensor Are Off, the Pump is Off
9. If the Hot Temperature, Wet Humidity, and FC-37 Sensor Are Off, the Pump is Off
10. If Cold Temperature, Dry Humidity, and FC-37 Sensor is On, Pump is On
11. If the Cold Temperature, Humidity, and FC-37 Sensor is On, the Pump is Off
12. If Cold Temperature, Wet Humidity, and the FC-37 Sensor Are On, the Pump Is Off
13. If Normal Temperature, Dry Humidity, and FC-37 Sensor Are On, the Pump is On
14. If Normal Temperature, Humidity, and FC-37 Sensor is On, then Pump is On
15. If Normal Temperature, Wet Humidity, and FC-37 Sensor Are On, Pump is On
16. If Hot Temperature, Dry Humidity, and FC-37 Sensor Are On, Pump Is On
17. If the Hot Temperature, Humidity, and FC-37 Sensor are On, the Pump is On
18. If the Hot Temperature, Wet Humidity, and FC-37 Sensor are On, the Pump is On

d. Defuzzification

At the defuzzification stage, a calculation process from determining the value at the fuzzification stage is used as a rule and will produce crisp output [17]. In the Sugeno method using the Weight Average (WA) calculation, it can be seen in Equation 1:

$$WA = \frac{\sum_{n=1}^{18} a_n z_n}{\sum_{n=1}^{18} a_n} \tag{1}$$

$$Rulescore = a_1 z_1 + a_2 z_2 + a_3 z_3 + a_4 z_4 + \cdots + a_n z_n \tag{2}$$

$$Defuzscore = a_1 + a_2 + a_3 + a_4 + \cdots + a_n \tag{3}$$

Description:
WA = Average score
Rule score = The sum of the results of multiplying the predicate value with the output value index
Defuzzied score = Sum of predicate values up to – n
an = Value of the nth rule predicate
zn = Index output value (constant) to – n

The result of the calculation in the defuzzification stage is in the form of a constant that states whether the desalination process occurs automatically or not. Like in the example below, in the application of fuzzy calculations, the output for the defuzzification stage cannot be produced before the fuzzification stage is completed. Figure 4 is a projection of the rules generated after the process of determining the linguistic variables, and these rules look at the Sugeno fuzzy design, which has 18 rules that are applied to the fuzzification process. Figure 5 initiates input variables from sensors such as the dht11 sensor, the salt level sensor, and the rain sensor.

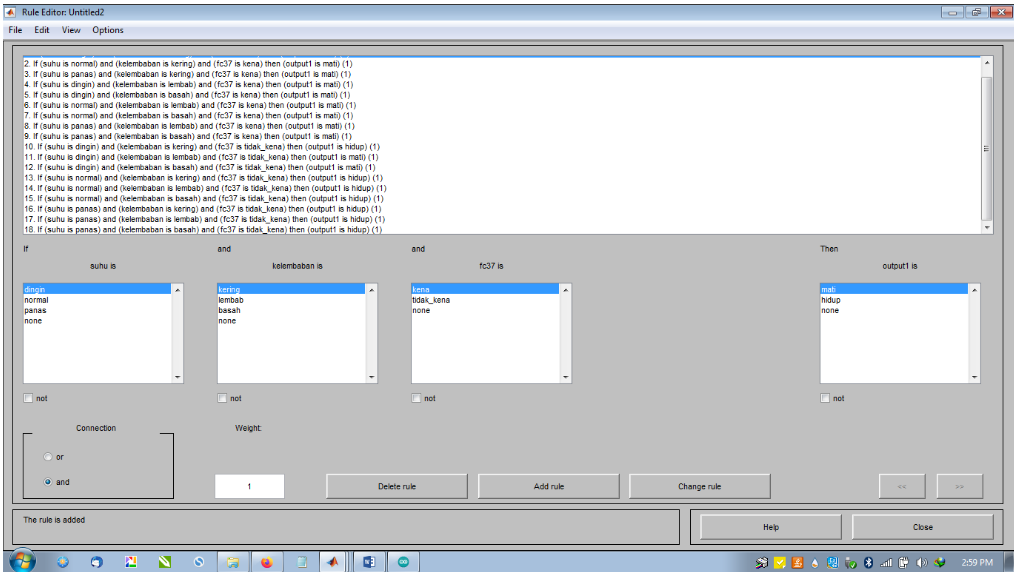


Figure 4. Rules

```
  float t = dht.readTemperature();
  float k = dht.readHumidity();
  //read the analog in value:
  sensorValue = analogRead(analogInPin);
//  int inputsuhu = random(15, 50);
  String stringsuhu = katasuhu+t;
//  int inputlembab = random(20, 70);
  String stringlembab = katalembab+k;
  int hujan=digitalRead(capteur_D);
```

Figure 5. Sensor Variable

In Figure 6 the HW-038 sensor will read the water level in the fresh water container and give the condition if the water level less than the specified height limit, the program will continue the calculation from the salt level sensor. After that, the variable that has been determined to be the limit of the salt content will determine the type of water.

```
watervalue = analogRead(SIGNAL_water);
if(watervalue<250){
  //Mathematical Conversion from ADC to conductivity (uSiemens)
  //rumus berdasarkan datasheet
  outputValueConductivity = (0.2142*sensorValue)+494.93;

  //Mathematical Conversion from ADC to TDS (ppm)
  //rumus berdasarkan datasheet
  outputValueTDS = (0.3417*sensorValue)+281.08;
  if(outputValueTDS<=500){
    jenis=tawar;
  }
  else if(outputValueTDS<=30000){
    jenis=payau;
  }
  else{jenis=Asin;}
```

Figure 6. Reading of State Water Level

In Figure 7, the process of entering the sensor variable for the fuzzification process and removing the value of the defuzzification in the output variable is shown.

```
fuzzy->setInput(1, t);
fuzzy->setInput(2, k);
fuzzy->setInput(3, hujan);
// Running the Fuzzification
fuzzy->fuzzify();
// Running the Defuzzification
float output = fuzzy->defuzzify(1);
```

Figure 7. Fuzzification Process

Figure 8 is a branching condition that determines the value of the output variable after the defuzzification process to drive the water pump from the power supplied by the relay.

```
  if(output==1){
    digitalWrite(RELAY_PIN, HIGH);
  }
  else if(output==0)
  {  digitalWrite(RELAY_PIN, LOW);}
}
```

Figure 8. Relay Branch

Figure 9 is a line of code to display the results of the temperature and humidity sensor readings and the type of water that has evaporated.

```
lcd.setCursor(0,0);
lcd.print(stringsuhu);
lcd.setCursor(0,1);
lcd.print(stringlembab);
delay(1000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("Jenis Air :");
lcd.setCursor(0,1);
lcd.print(jenis);
delay(1000);
lcd.clear();
```

Figure 9. Code Lines LCD Display

3. RESULT AND DISCUSSION

Hardware tool testing is done to find out how effective the tool is in automatic water desalination devices. Referring to the existing test design, for the testing process for hardware tools, tests will be carried out such as sensor testing, fuzzy logic testing, and testing automatic mini water pumps. The ruslts can be seen in the Table 3.

Table 3. Results

No	Time	Relay & Pump	Temperature	Humidity	FC-37	Fuzzy Output	Water Type	Embedded Salinity (ppt)	Salinity-615 (ppt)	Error Percent (%)
1	Thursday, 14 October 2021 13:06:00	On	45.7˚C	24%	No water	1 (On)	Fresh	-	-	-
2	Thursday, 14 October 2021 13:06:30	On	45.4˚C	24%	No water	1 (On)	Fresh	-	-	-
3	Thursday, 14 October 2021 13:07:00	On	44.8˚C	25%	No water	1 (On)	Fresh	-	-	-
4	Thursday, 14 October 2021 13:07:30	On	43.2˚C	25%	No water	1 (On)	Fresh	-	-	-
5	Thursday, 14 October 2021 13:08:00	On	42.6˚C	27%	No water	1 (On)	Fresh	-	-	-
6	Thursday, 14 October 2021 13:15:00	Off	36.3˚C	31%	Ada	0 (Off)	Fresh	-	-	-
7	Thursday, 14 October 2021 13:15:30	Off	36.3˚C	31%	Ada	0 (Off)	Fresh	-	-	-
8	Thursday, 14 October 2021 13:16:00	Off	36.2˚C	31%	Ada	0 (Off)	Fresh	-	-	-
9	Thursday, 14 October 2021 13:16:30	Off	36.4˚C	31%	Ada	0 (Off)	Fresh	-	-	-

No	Time	Relay & Pump	Temperature	Humidity	FC-37	Fuzzy Output	Water Type	Embedded Salinity (ppt)	Salinity-615 (ppt)	Error Percent (%)
10	Thursday, 14 October 2021 13:17:00	Off	36.1˚C	32%	Ada	0 (Off)	Fresh	-	-	-
11	Thursday, 25 November 2021 14:20:00	On	30.8˚C	42%	No water	1 (On)	Fresh	0.331	0.2	66.9
12	Thursday, 25 November 2021 14:20:30	On	31˚C	41%	No water	1 (On)	Fresh	0.325	0.2	67.5
13	Thursday, 25 November 2021 14:21:00	On	31˚C	40%	No water	1 (On)	Fresh	0.318	0.2	68.2
14	Thursday, 25 November 2021 14:21:30	On	30.7˚C	42%	No water	1 (On)	Fresh	0.322	0.2	67.8
15	Thursday, 25 November 2021 14:22:00	On	30.5˚C	42%	No water	1 (On)	Fresh	0.318	0.2	68.2
16	Thursday, 25 November 2021 14:35:00	Off	30.4˚C	33%	Ada	0 (Off)	Fresh	0.326	0.2	67.4
17	Thursday, 25 November 2021 14:35:30	Off	30.7˚C	34%	Ada	0 (Off)	Fresh	0.331	0.2	66.9
18	Thursday, 25 November 2021 14:36:00	Off	30.6˚C	34%	Ada	0 (Off)	Fresh	0.347	0.2	65.3
19	Thursday, 25 November 2021 14:36:30	Off	30.1˚C	35%	Ada	0 (Off)	Fresh	0.325	0.2	67.5
20	Thursday, 25 November 2021 14:37:00	Off	30.3˚C	35%	Ada	0 (Off)	Fresh	0.323	0.2	67.7

The analysis of the evaporation results obtained from the temperature and humidity parameters will affect the volume of water that will evaporate. This can be written with the evaporation flux formula found by Irving Langmuir which was further developed by Heinrich Hertz and Martin Knudsen with formula 4 as follows [18][19]:

$$\frac{\mathrm{d}M}{\mathrm{dt}} = (\mathrm{p_v} - \mathrm{p_p})\sqrt{\frac{\mathrm{m}}{2\pi \mathrm{RT}}} \quad (4)$$

$\frac{dM}{dt}$ = mass flow rate (kg) over a certain area (m-2) in one second (second, s-1), so the unit is kg/(m^2 s)

Pv = vapor pressure at a certain temperature, or boiling point pressure at a certain temperature, in units of pascals (pa)

Pp = the vapor partial pressure of the substance in the gas mixture (pa)

m = molecular weight of water (0.01801528 kg/mol)

R = ideal gas constant or Mendeleev's constant = 8.314 Joules/(mol Kelvin)

With the criteria obtained from the monitoring results and the size of the tool, the following values can be obtained:

Diameter of heating container =21.7cm

The height of the heating container that has been determined = 5cm

Surface area of heating container =1079.9873 cm2 -> 0.10799873 m2

Observed temperature = 45.7 C -> 318.85 K

Observed humidity = 24%

Humidity Ratio at maximum humidity = 0.06768570921439611 kg/kg

Humidity ratio at 24% = 0.01503720572349713
Mole weight of seawater (m) = 0.018 kg/mol
Pressure atmosphere=101325 pa
Based on equation 5 can be applied as follows:

$$p_v = \frac{Hr_{100\%}\ P_a}{0.62198 + Hr_{100\%}} \tag{5}$$

So, the result of the vapor pressure is 9944,317 pascals
Based on equation 6 can be applied as follows:

$$p_v = \frac{Hr_{24\%}\ P_a}{0.62198 + Hr_{24\%}} \tag{6}$$

So, the result of partial pressure is 2386.641821281 pascal.
The rate of evaporation of water is
$\frac{dM}{dt}$= 7.85663034549746366220029122001 kg/(m^2 s)
This is the maximum evaporation that can occur under these conditions. So, for a surface area of water of 0.10799873 square meters, the water will evaporate at 0.84850 kg per second. With a density of 1 kg/liter of water, the volume of evaporated water is 3054.6219 liters per hour. But the actual evaporation is lower, which is about 1/100,000 to 1/1,000,000 smaller than the calculation when the desalination water results are taken. You can only get 1 cup of water containing 200ml for 2 weeks while the desalination process is running. This is due to the presence of a layer of water vapor on the surface of the water, which is close to the saturated vapor condition. So, evaporation is much smaller.As quoted from Frank E. Jones' book entitled Evaporation of Water with Emphasis on Applications and Measurements. Jones quotes this opinion from De Boer in the book The Dynamical Character of Adsorption [20].

4. CONCLUSION

The automatic water desalination device with fuzzy logic in the Tangkil Beach case study can perform the water desalination process automatically by using the DHT11 sensor to enter temperature and humidity and the FC-37 sensor to enter the water level. This makes the main parameters inputs that will be processed on the Arduino Mega board. The fuzification process continues to provide output to the relay to drive the pump. The calculation of fuzzy logic includes the following steps: the formation of linguistic variables; the establishment of 18 rule bases; the formation of system inference; and defuzzification calculation.

Fuzzy logic calculations are carried out by forming linguistic variables whose input is in the form of numbers that are mapped within a certain range. Then the test uses Matlab software to determine the results of the fuzification calculation, which has 18 rules. After the rules are determined, the calculation process continues by using equation 2.1 to find out the average weight of each of the specified rules so that its inclination to one rule can be determined and it will issue an output to turn the pump on or off.

The automatic water desalination device with fuzzy logic in the Tangkil Beach case study identifies the type of water that has passed through the water desalination process using a salt level sensor that has been implanted to identify the type of water. With a standard known salt content of 0–0.5 ppt including fresh water, ranging from 0.5–30 ppt for brackish water, and more than 30 ppt for sea water, in the monitoring results from the comparison between the implanted salt level sensor and conventional salt level measuring instruments, the results are quite different in the read salt content. This happens because of the difference in the readings of the salt level measuring instrument, which only has a value of 1 digit behind the comma, so that when compared to the salt level sensor (embedded), which can read 3 digits behind the comma, it has a high percentage of error. However, this error percentage is still affordable based on the tolerance value if the range of salt content parameters from 0 ppt to 199.9 ppt is compared to the tolerance value of ±2%.

The automatic water desalination device with fuzzy logic of the Tangkil beach case study has inputs in the form of temperature, humidity, and water level from the FC-37 sensor. All these inputs are mapped to linguistic variables. Temperature and humidity are the main parameters for evaporation. The results obtained from the study showed that the greater the temperature but the lower the humidity level, the faster the heat transfer process, so that the evaporation process will be faster too. With the humidity conditions tested in the study, the results obtained showed monitoring temperatures of 45.7˚C and humidity of 24%. The results of this monitoring state that these parameters, hot temperature and dry humidity, have an estimated large evaporation yield of 3054.62 liters/hour, but these results are very far from the reality of the evaporation results obtained. This occurs due to changes in humidity and temperature that can occur at any time in the weather outside, and there is also water vapor near the saturation point, as described by Frank E. Jones in the book entitled Evaporation of Water With Emphasis on Applications and Measurements. The estimated yield of this evaporation calculation has an actual yield ratio of 1/100000 to 1/1000000.

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