CHAPTER 5
IMPLEMENTATION AND RESULTS

5.1. Implementation

This section is an implementation of predefined fuzzification into Arduino code. Fuzzification will process data from each sensor according to a predetermined value.

```
void FuzzifikasiSuhu() { if (temperature <=25)  { suhu[0] = 1;}
        else if (temperature>25 && temperature<=30) { suhu[0]=(30 - temperature) /(30
- 25);}
        else  { suhu[0] = 0; }
        … }

void FuzzifikasipH() {if (pH <=6) { pHAir [0] = 1;}
        else if (pH > 6 && pH <= 6,8) { pHAir [0] = (6,8 - pH) / (6,8 - 6); }
        else if( pH >=6,8)  { pHAir [0] = 0; }
        …}

void FuzzifikasiKekeruhan() {if (teg <=2) { keruh[1] = 1;}
        else if (teg > 1,5 && teg <= 2){ keruh[1] = (2 - teg) /(2 - 1,5); }
        else { keruh[1] = 0;}
        …}
```

The above program code is an example of fuzzification for each sensor. The amount of program code follows how many variables each sensor will process. For example, the temperature sensor has three variables that are processed, namely cold, hot and normal. Then, in the program code, there are also three variables with the rules and values that have been previously determined when grouping membership functions.

The program code below is the code to find a suitable rule base from the fuzzification results, where the fuzzification output is as fuzzy numbers such as 0,

1 and 2. The program code R01-R18 is a container that will contain values according to the rules that have been made.

```
void Rules(){
 int i, j, k;
 int no=1;
 for ( i=0; i<=2; i=i+1){
   for ( j=0; j<=2; j=j+1){
     for ( k=0; k<=1; k=k+1){
        temp = min(min(suhu[i], pHAir[j]),keruh[k]);
        R [i][j][k] = temp;
     }
   }
 }
R01 = R[0][0][0]; //(Dingin, Asam, Jernih = On)
R02 = R[0][0][1]; //(Dingin, Asam, Keruh = On)
R03 = R[0][1][0]; //(Dingin, Netral, Jernih = Off)
…
R18 = R[2][2][1]; //(Panas, Basa, Keruh = On)
}
```

Defuzzification is changing the results of the previous stage into an output that has a definite value. The method to find the defuzzification value on the Sugeno fuzzy uses the Weight Average (WA) method. Below is the program code to calculate the defuzzification value, where On-Off is an output declaration that has values 0 and 1.

```
void Defuzzification(){
Off=1; On= 2;
outputX = (R01*On)+(R02*On)+(R03*Off)+. . .(R18*On);
outputY = (R01+R02+R03+ . . . R18);
resultDef = outputX / outputY;
```

Before looking for the defuzzification value using the Weight Average (WA) you must add up the value of the rule base which is multiplied by the value according to the output (on/off) and place it in the outuptX variable. To find outputY, you must add up the value of the rule base. Then the result of the outuptX value is divided by the outuptY value, then the deffuzification value will be obtained. The program code below is used to determine whether the output as a buzzer will turn on or off. If the defuzzification value is more than 1 and less than 2, then the buzzer will turn off, and if the defuzzification value is equal to 2, then the buzzer will turn on.

```
if(resultDef >1 && resultDef <2){
    digitalWrite(buzz, LOW);
  }
else if(resultDef =2){
    digitalWrite(buzz, HIGH);
  }
```

5.2. Result

Table 3 results from temperature sensor calibration. From the calibration, 100 data were obtained from each condition, then the average value was sought from the data. For warm conditions, the average value is 52.91^{o}C, normal conditions are 28.19^{o}C, and for cold conditions it is 23.52^{o}C. Figure 13 is a sample of water used for calibration of the temperature sensor. The water used is hot, cold and plain water.

Table 3: Temperature sensor calibration

Warm	Normal	Cold
33,56	29,94	28,5
44,69	29,12	26,44
49,63	28,75	25,25
52,19	28,5	24,56
53,56	28,37	24,06
54,38	28,31	23,75
53,56	28,06	23,12
53,44	28,06	23,19
53,13	28,06	23,19
53,00	28,06	23,19
52,94	28,06	23,19
52,81	28,06	23,25
52,69	28,06	23,19
51,35	**28,30**	**23,90**

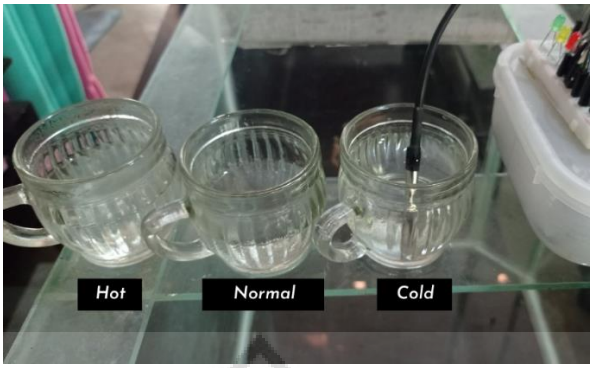

Figure 13: Water for temperature calibration

Table 4 results from pH sensor calibration using pH buffers of 6.86 and 4.01. Based on the calibration process, 182 data were obtained, then the average value was taken from this data. For pH buffer 6.86, the average value is 6.96, with an average voltage value of 3.08. While the pH buffer is 4.01, the average value is 3.97, with an average voltage value of 2.61. Figure 14 is the water used for calibration of the pH sensor. The water used is aqua water that has been mixed with pH powder, whose values have been known, such as pH 4.01 and pH 6.86.

Table 4: pH sensor calibration table

pH Buffer 6,86		**pH Buffer 4,01**	
Voltage	**pH**	**Voltage**	**pH**
3,1	7,07	2,6	3,95
3,09	6,97	2,61	3,98
3,1	7,07	2,62	4,04
3,07	6,88	2,63	4,11
3,09	6,97	2,6	3,95
3,09	6,97	2,6	3,95
3,08	6,94	2,61	3,98
3,1	7,04	2,6	3,92
3,08	6,91	2,61	3,98
3,09	6,97	2,63	4,11
3,08	6,91	2,61	4,01
3,08	6,94	2,61	3,98
3,08	6,91	2,6	3,95
3,08	6,91	2,6	3,95

Figure 14: Water for pH calibration

Table 5 results from the calibration of the turbidity sensor using 3 types of water, namely coffee, clean water and water that have been mixed with soil. The calibration process gets 100 data, from this data the average value is taken. coffee water with an average tension of 0.9 clean water 2.8 and water mixed with soil 2.2. of the average value of the stress is taken as a reference to determine the level of water turbidity. Voltage less than 2 is cloudy water, voltage over 2 is clean. Figure 15 is a sample of water used for calibration of the turbidity sensor. The water used for calibration is aqua water, coffee and tea water.

Table 5: Turbidity sensor calibration table

Coffee		**Tea**		**Clean Water**	
Voltage	**Turbidity**	**Voltage**	**Turbidity**	**Voltage**	**Turbidity**
1	75,96	1	75,96	3	27,88
1	75,96	1	75,96	3	27,88
1	75,96	1	75,96	3	27,88
1	75,96	1	75,96	3	27,88
1	75,96	1	75,96	3	27,88
1	75,96	1	75,96	3	27,88
1	75,96	1	75,96	3	27,88
1	75,96	2	51,92	3	27,88
1	75,96	3	27,88	3	27,88
1	75,96	2	51,92	3	27,88
1	75,96	2	51,92	3	27,88
1	75,96	2	51,92	3	27,88
1	75,96	2	51,92	3	27,88
Average					
0,9	**79,2**	**2,2**	**47,9**	**2,8**	**33,6**

Figure 15: Water for turbidity calibration

At this stage, testing is carried out for all systems. Table 6 is the first trial sample, tested using aqua water with no water mixture. From the results of the first trial, it was found that the temperature was very stable at 26.31. The turbidity value is also stable, even though there are several errors. The pH value for the overall test is less stable, as the pH sensor is very sensitive to changes in water content. The test results get the average value for pH 6.50. The defuzzification result shows a value below 2, which means the buzzer is off. If the defuzzification value is 2 or more, the buzzer will turn on.

Table 6: Table testing 1

Temperature	Temperature Fuzzification			pH	pH Fuzzification			Turbidity	Turbidity Fuzzification		Deff
	Dingin	Normal	Panas		Asam	Netral	Basa		Jernih	Keruh	
26,31	0,74	0,26	0	6,71	0,64	0,36	0	2,23	1	0	1,42
26,31	0,74	0,26	0	3,69	1	0	0	2,23	1	0	1,74
26,31	0,74	0,26	0	7,44	0,28	0,72	0	2,23	1	0	1,18
26,31	0,74	0,26	0	7,78	0,11	0,89	0	2,22	1	0	1,09
26,31	0,74	0,26	0	6,01	1	0	0	2,22	1	0	1,73
26,31	0,74	0,26	0	6,01	1	0	0	2,22	1	0	1,73
26,31	0,74	0,26	0	6,89	0,55	0	0	0,45	1	0	1,36
26,31	0,74	0,26	0	4,03	1	0	0	2,22	1	0	1,74
26,31	0,74	0,26	0	5,03	1	0	0	2,21	1	0	1,74
26,31	0,74	0,26	0	7,5	0,25	0,75	0	2,2	1	0	1,17
26,31	0,74	0,26	0	7,35	0,32	0,68	0	2,2	1	0	1,21
26,31	0,74	0,26	0	7,14	0,43	0,57	0	2,2	1	0	1,28
26,31	0,74	0,26	0	6,19	0,9	0,1	0	2,2	1	0	1,63

Table 7 is the second program trial. In this second trial, aqua water was mixed with 250 ml of cold water, 250 ml of water mixed with soil, and 200 ml of soapy water. Water mixing is done every 15 minutes for 1 hour so that the sensor can read properly. In the second trial, the temperature and turbidity sensors were stable. The pH sensor for the second test is very unstable because the sensor is very sensitive to changes.

Table 7: Table testing 2

Temperature	Temperature Fuzzification			pH	pH Fuzzification			Turbidity	Turbidity Fuzzification		Deff
	Dingin	Nor-mal	Panas		Asam	Netral	Basa		Jernih	Keruh	
24,75	1	0	0	5,4	1	0,0	0	1,8	0,0	1,0	2,0
24,75	1	0	0	-1,8	1	0,0	0	1,8	0,0	1,0	2,0
24,75	1	0	0	14,7	-3,4	4,4	0	1,8	0,0	1,0	2,0
24,75	1	0	0	6,4	0,8	0,2	0	1,8	0,0	1,0	1,8
24,75	1	0	0	0,2	1	0,0	0	1,9	0,0	1,0	2,0
24,75	1	0	0	-1,0	1	0,0	0	1,9	0,0	1,0	2,0
24,75	1	0	0	1,7	1	0,0	0	1,9	0,0	1,0	2,0
24,75	1	0	0	11,9	-2	3,0	0	1,9	0,0	1,0	2,0
24,75	1	0	0	11,5	-1,8	2,8	0	1,9	0,0	1,0	2,0
24,75	1	0	0	13,1	-2,5	3,5	0	1,9	0,0	1,0	2,0
24,81	1	0	0	4,2	-0,7	1,7	0	1,8	0,0	1,0	2,0
24,81	1	0	0	0,0	1	0,0	0	1,7	0,0	1,0	2,0
24,81	1	0	0	15	-3,5	4,5	0	1,3	0,0	1,0	1,8

Table 8 shows the results of the 3rd testing. The third test, mixing 200 ml of warm water and 200 ml of water mixed with soil, so that the sensor can read the maximum water mixing done every 10 minutes. The results of the third test show the sensor value is stable. The temperature sensor is at 30.3, the turbidity sensor is at 0.95-1.05 and the pH sensor is at 4.8-5.3. Shows a pH value below 6.8 which means the buzzer is on.

Table 8: Table testing 3

Temperature	Temperature Fuzzification			pH	pH Fuzzification			Turbidity	Turbidity Fuzzification		Deff
	Dingin	Normal	Panas		Asam	Netral	Basa		Jernih	Keruh	
30,62	0	0,88	0,12	5,83	1	0	0	0,93	0	1	2
30,5	0	0,9	0,1	6,44	0,78	0,22	0	0,88	0	1	2
30,37	0	0,93	0,08	4,36	1	0	0	0,92	0	1	2
30,31	0	0,94	0,06	4,64	1	0	0	0,95	0	1	2
30,31	0	0,94	0,06	5,31	1	0	0	1,04	0	1	2
30,31	0	0,94	0,06	4,88	1	0	0	1,04	0	1	2
30,31	0	0,94	0,06	5	1	0	0	1,05	0	1	2
30,31	0	0,94	0,06	4,82	1	0	0	1,04	0	1	2
30,31	0	0,94	0,06	4,91	1	0	0	1,05	0	1	2
30,31	0	0,94	0,06	5,49	1	0	0	1,03	0	1	2
30,31	0	0,94	0,06	4,67	1	0	0	1,04	0	1	2
30,31	0	0,94	0,06	5,31	1	0	0	1,03	0	1	2
30,25	0	0,95	0,05	5,12	1	0	0	1,04	0	1	2