Smart Sensor Device for Detection of Water Quality as Anticipation of Disaster Environment Pollution

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***Abstract*— Population growth and the pace of development have resulted in environmental degradation, especially the quality of surface water or groundwater. This situation occurs in urban areas with large populations, and / or downstream. Raw water quality tends to decline; this condition becomes the central issue in the provision of clean water in Indonesia. In many places, the quality of ground water and river water as drinking water healthy for people less qualified, even in some places is not worth drinking. These conditions forced the poor still use the water for their daily needs so that it can have an impact on their health. Potable water has a certain standard indicators, namely: indicators of physical, chemical, and biological. The parameters used to determine these indicators include the degree of acidity (pH), total dissolved solids (TDS), transparency or turbidity and water temperature. This study makes a water quality detection tools by using four parameters above. The threshold parameter pH = 6.5 - 8.5, TDS <1000ppm, turbidity <5 NTU, and the water temperature = ± 3C than the air temperature. Precision test of sensors has been carried out and each sensor has a good precision, with an average percentage error for sensor pH = 1.46%, sensor TDS = 1:09%, turbidity sensor = 2:00%, and a water temperature sensor = 0.83%. Determination of water quality using fuzzy logic, divided into three categories: water quality is good, less good and bad. The experimental results in some places of the water source was obtained detection of water quality accurately: (1). Water quality is good for water from the local government water company of Surabaya and Malang; mountain spring water, wells water in Malang; and aqua water, (2). Water quality is less good for wells water in Surabaya, and (3). Poor water quality for tap water mixed with soap.**

Keywords—smart sensor device, detection, water quality

I. Introduction

Research on water quality has been done, well water for household consumption as well as sea water and lake water. The methods used vary, one using multispectral [1], [2], [3], [4], [5]; the use of artificial intelligence network NN, quality of the water can be detected and monitored [6].

Smart sensors have been used to determine and monitor the quality of sea water [7] and for water consumed [8]. Smart sensors used in the study were a double function, namely the detection and monitoring. This research is the first year (the first step), using smart sensors to detect water quality of well water and tap water also. The sensor used is a water sensor, pH, TDS, and turbidity.

II. System Design

In this section discussed the design of mechanical hardware system and software system design. Illustration of the overall system is shown in Fig.1. In the picture shown sensor devices, control device, crane, and Global Positioning System (GPS). The main devices of sensor unit consists of air temperature sensor, water temperature sensor, acidity (pH) sensor, total dissolved solids (TDS) sensor, turbidity sensor, and water surface sensor. The minimum system used is ATmega2560. The main devices of control unit are an ATmega2560 microcontroller, DC motor, and rotary encoder. Delivery of sensor data from the sensor unit to the control unit using XBee module. Devices on the sensor unit, control unit, and the flow of sensor data transmission is depicted in Fig.2.

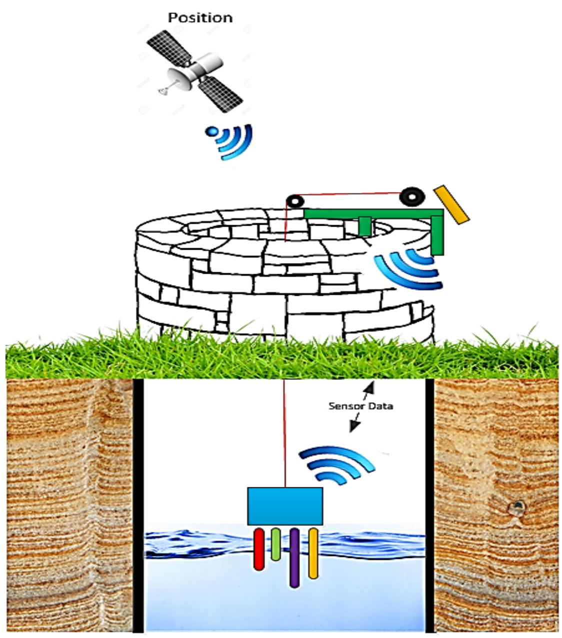


Fig.1. Illustration of the overall system.

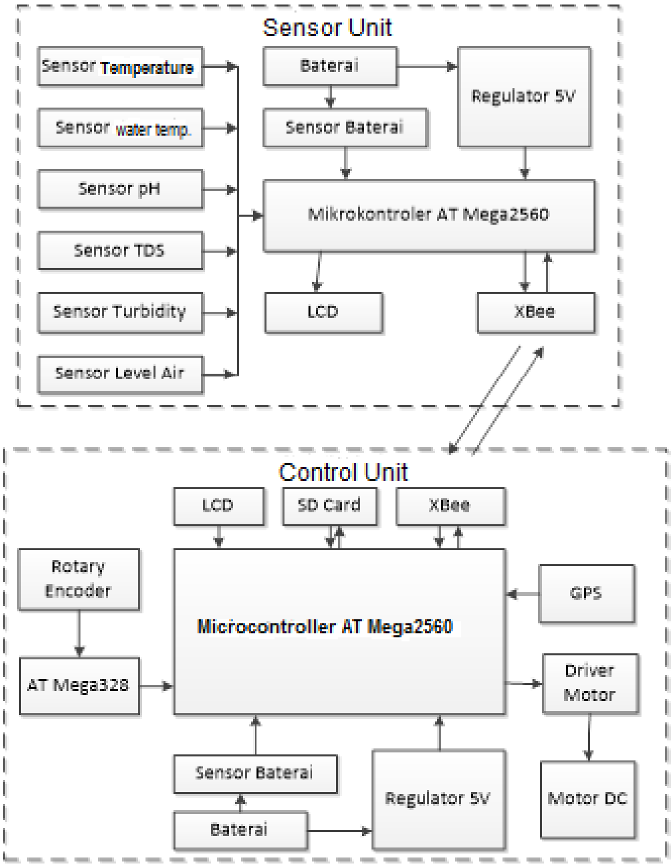
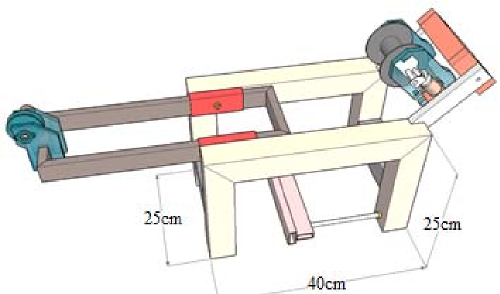


Fig.2. System design of sensor data acquisition.



(a)


(b)

Fig. 3. (a). Design of crane, (b).Its implementation

2.1. System Design for Mechanical Hardware

In this sub-section explains the design of the crane, the control unit and the sensor unit.

A. Design of Crane

Crane serves to lower the sensor unit into the well. There are two main parts in the crane: pulleys and rollers. Pulleys serve as capstan the steel wire used by sensor unit for going down to the wellbore. The movement of the pulley is managed by the control unit using mokrokontroler ATmega2560 and IC driver motor L298D. While rollers is used to measure the distance of steel wire that lowered into the well. Sensor Incremental Rotary Encoders 100p / r is used for distance calculations. Data from the sensors rotary encoder is processed by microcontroller (ATmega328) and sent to the control unit in parallel 10-bit in the form of distance value. Design and implementation of crane is shown in the Fig.3.

B. Design of Control Unit

The control unit is the main part of this system. The function of the Control Unit: (i). Controlling the motor crane; (Ii). Receiving and processing data from sensor unit; (Iii). Receiving position data from the GPS; and (iv). Making decision of water quality using fuzzy logic. 3D design and implementation of the Control Unit is shown in Fig.4.

C. Design of Sensor Unit

The sensor unit is a device that serves to observe the well water linked to temperature, acidity, turbidity and levels of dissolved substances (TDS). The sensor used is a water temperature sensor, pH, turbidity and TDS. The task of sensor units are (i). Read the conditions associated with the water temperature, pH, turbidity and TDS; (Ii). Read the conditions of air temperature; and (iii). Sending sensor data to the control unit. The design of the sensor unit in the form of 3D images and its implementation is expressed in Fig.5.

2.2. System Design for Fuzzy Logic

The design software on this system contains the programming algorithm of automatic systems that run on this system. Making software/program in the microcontroller using the Arduino IDE. Furthermore, the program will be stored in the data memory and program memory. Software design is to discuss the program interface input and output devices on the system.

In the software design process of fuzzy logic requires the development of a program that is used to determine the parameters required in the process of writing a fuzzy program. Flowchart process of fuzzy logic is stated in Fig.6.

A. Design Crisp Input and Crisp Output

The first step, the process of making fuzzy logic system at the start with determination and manufacture crisp input and output. Fuzzyfication change numerical crisp input into linguistic value. For instance, the input crisp 100 degrees transformed into a linguistic variable such as "low". This study have used four inputs and one output. Inputs were obtained from the value of temperature sensors, pH, TDS, and turbidity. Total membership functions used are three types of triangles. The first step, the input of the membership function is determined for each input, then the value is processed using fuzzyfication in realtime. After that, a comparison is made between the value and the information of the membership function stored, to generate a fuzzy input value. Some of chemically derived contaminants are turbidity, pH, and TDS that have save value for the water (drinking water) stated in [9], [10], [11]. Based on [9], [10], [11], Table 1 was created, it was value of crisp input and crisp output for four inputs (temperature, pH, turbidity, and TDS) and one output.

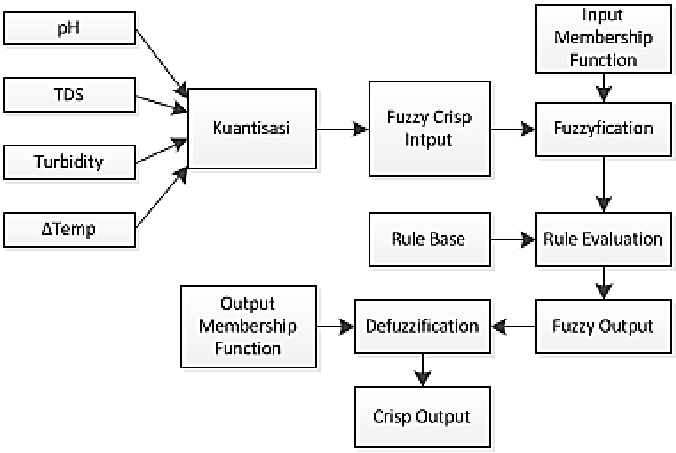


Fig.6. Flowchart fuzzy logic

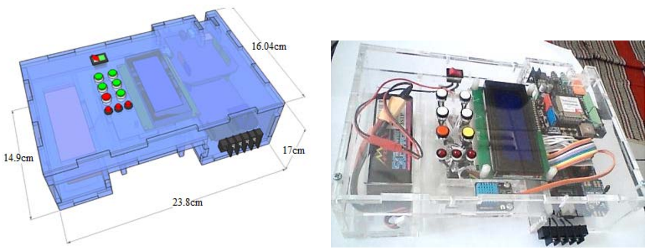


Fig. 4. Design of control unit (left) and its implementation (right).

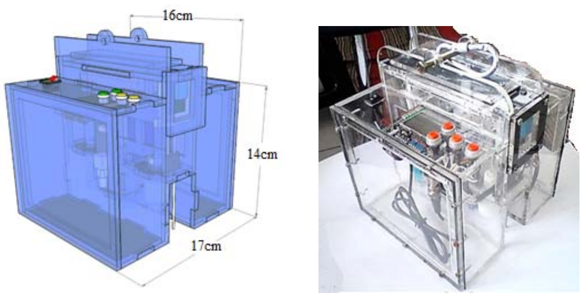


Fig. 5. Design of sensor unit (left) and Its Implementation (right).

B. Membership Functions

Membership function is used to declare function of overall system. Forms of membership functions used are triangular, the number of label 12 units for inputs (three labels for each input: temperature, pH, turbidity and TDS) and output. Each input of crisp in the fuzzy system, has many labels that refer to it. In general, the number of labels refer to the input variable described. The higher the resolution of the resultant, fuzzy control system will give out a better response.

TABLE 1. Value of crisp input and crisp output

Crisp Input			Crisp Output	
Parameters	Range	Value	Decision	Value
TDS (ppm)	0 - 250	Good	Bad	10
	100 - 300	Enough	Less good	5
	250 - 1000	Bad	Good	0
Turbidity (NTU	0 - 3	Transparent		
	2 - 5	Enough		
	4.5 - 10	Turbid		
pH	0 - 6	Acid		
	6 - 8	Neutral		
	8 - 15	Alkali		
ΔT (°C)	0 - 2	Good		
	1 - 3	Enough		
	2 - 10	Bad		

Membership function of temperature has three input variables, good: 0-1.5, enough: 1-3, and bad: 2.5-10. Membership function of pH also has three input variables, namely acid: 0-6.5, neutral: 5.5-8.5, and alkaline: 7.5-15. While turbidity membership function has three input variables, transparency: 0-2, enough: 1-5, turbid: 4-10. TDS membership function also has three input variables, namely good: 0-300, enough: 200-500, bad: 400-1000. Membership function of output is expressed in the quality of water and has three labels are bad = 10, less good = 5, and good = 0. Membership function of output is depicted in Fig.7.

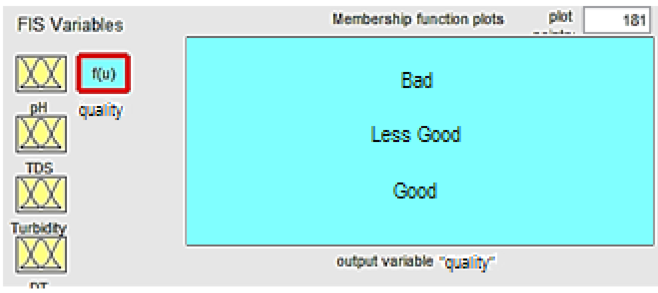


Fig.7.Membership function of water quality.

C. Rule Base of Fuzzy Logic

Rule base is a collection of fuzzy rules which connects between input and output. In this study, the rule base is created to regulate the decision of fuzzy logic in terms of water quality. Rule base is the basis of the decision to get the output action from some input conditions, based on the rules which have been set. Defining some rules depending on the needs and be adapted with the data that is defined in the quantization table. This study uses a rule base as shown in Table 2.

III. TESTING OF PRECISION SENSORS

In this session describes the testing of sensors that have been designed to get the precision of those sensors.

3.1. Testing Sensor DS18b20

This study uses a DS18B20 temperature sensor to measure the temperature of the water was observed. Based on testing of temperature sensors, the result is as expected with the smallest percentage error of 0.1% and largest 2.96%. It can be said that this temperature sensor has a level of accuracy that is good enough that deserves to be used. Figure 8 shows testing of sensor the water temperature and comparison testing between measuring instrument and sensor the water temperature, DS18B20 are shown in Table 3.

TABLE 2. Rule base of fuzzy logic.

	TDS	Good			Enough			Bad		
pH	ΔT / Turbid	Transparent	Enough	Turbid	Transparent	Enough	Turbid	Transparent	Enough	Turbid
Acid	Transparent	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad
	Enough	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad
	Turbid	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad	Bad
Neutral	Transparent	Good	Good	Good	Good	Good	Less	Less	Less	Bad
	Enough	Good	Good	Less	Good	Good	Less	Less	Less	Bad
	Turbid	Less	Less	Bad	Less	Less	Bad	Bad	Bad	Bad
Alkali	Transparent	Less	Less	Bad	Less	Less	Bad	Bad	Bad	Bad
	Enough	Less	Less	Bad	Less	Less	Bad	Bad	Bad	Bad
	Turbid	Bad	Bad	Bad	Bad	Less	Bad	Bad	Bad	Bad

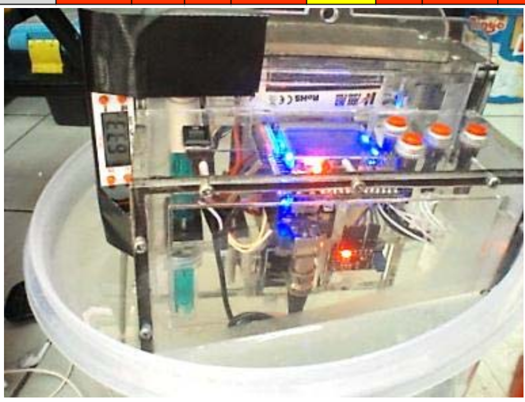


Fig.8. Measurement of water temperature using sensor of water temperature, DS18b20.

TABLE 3
Comparison of temperature measurement between measuring instrument and the water temperature sensor DS18b20.

Measuring instrument (^oC)	DS18b20 (^oC)	Error
62.60	60.75	2.96%
60.00	59.06	1.57%
57.90	57.19	1.23%
55.60	55.00	1.08%
53.90	53.44	0.85%
52.00	51.88	0.23%
47.60	47.69	0.19%
46.60	45.75	1.82%
41.10	41.06	0.10%
40.00	39.88	0.30%
37.00	36.88	0.32%
36.00	35.94	0.17%
35.00	34.88	0.34%
32.50	32.44	0.18%
28.90	28.60	1.04%

3.2. Testing Sensor DHT11

The temperature sensor DHT11 in this study are used to detect the temperature of the air surrounding the water was observed. Comparisons are made between the temperature scale DHT11 sensor and water temperature. Testing is done by comparing the temperature of the thermometer and sensor DHT11. Comparison between the temperature of the thermometer and the temperature sensor DHT11 shown in Fig.9. The difference between the room temperature and the water temperature is calculated, the difference is ± 3c ideal. Comparison of temperature measurement between thermometer and sensor DHT11 is depicted in Table 4.

Fig.9. Comparison of temperature measurement between thermometer (left side) and sensor DHT11 (right side).

TABLE 4
Comparison of temperature measurement between thermometer and sensor DHT11.

DHT11 (^oC)	Thermometer (^oC)	Error
60.00	61.50	2.50%
53.00	52.20	1.51%
49.00	49.00	0.00%
46.00	45.10	1.96%
45.00	44.10	2.00%
43.00	42.00	2.33%
39.00	39.00	0.00%
36.00	36.10	0.28%
34.00	35.40	4.12%
28.00	28.60	2.14%

3.3. Testing Sensor pH

The degree of acidity of the water was measured by using a pH sensor to water are observed. The results of measurements of pH sensor and pH Meter obtained as in Table 5. The biggest error = 76.67% and the smallest one is 0.14%. However, the results obtained, the largest error only occurs at pH <2 and pH> 7 wherein the pH of the clean water ranging from 5 till 8. The biggest error is only 4% for pH values above, so that the pH sensor is feasible used to measure acidity of the clean water.

Comparison of measurement acidity (pH) between pH meter and sensor pH was conducted and shown in Fig.10. While, measurement of acidity (pH) were performed by pH Meter and sensor pH and the comparison results is attached in Table 5.

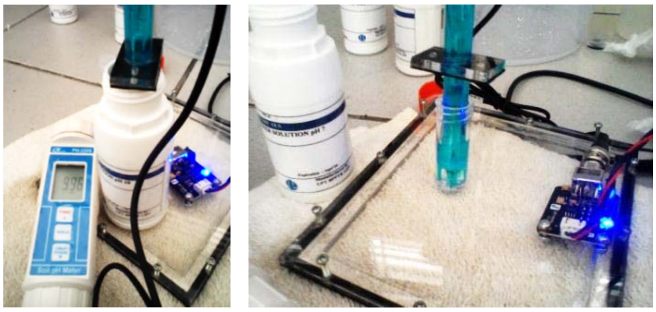


Fig.10. Comparison of measurement acidity (pH) between PH meter (life side) and sensor pH (right side).

TABLE 5
Comparison of measurement acidity (pH) between pH Meter and sensor pH.

pH Meter	Sensor pH	Error
0.30	0.53	76.67%
1.15	1.25	8.70%
2.14	2.19	2.34%
3.60	3.59	0.28%
3.90	4.06	4.10%
4.14	4.11	0.72%
5.01	4.94	1.40%
5.12	5.04	1.56%
5.23	5.15	1.53%
5.33	5.25	1.50%
5.43	5.35	1.47%
5.53	5.46	1.27%
7.01	7.02	0.14%
7.63	7.74	1.44%
9.95	10.8	8.54%

3.4. Testing Sensor TDS

TDS Sensor is used to measure the levels of dissolved substances in the water are observed. This measurement is done by comparing the value of the measuring instrument and sensor TDS.

The testing procedure: (1). Enter water into the jar; (2). Enter salt into the water and stir until dissolved; (3). Perform measurements on TDS TDS Meters and sensors. Repeat steps 2 and 3 to a maximum value of TDS.

Based on test results obtained TDS sensor results in line with expectations, where the percentage error 0.18% smallest and most large is 2.57%. This condition can be said that the TDS sensor has a level of accuracy that is good enough that deserves to be used. Comparison of measuremet total dissolved solids (TDS) between TDS Meter and sensor TDS is described in Table 6.

TABLE 6
Comparison of measuremet Total Dissolved Solids (TDS) between TDS Meter and sensor TDS.

TDS Meter (ppm)	Sensor TDS (ppm)	Error
451	456	1.11%
464	466	0.43%
473	480	1.48%
500	505	1.00%
516	519	0.58%
537	529	1.49%
558	559	0.18%
583	568	2.57%
663	656	1.06%
706	700	0.85%
791	803	1.52%

3.5. Testing Sensor Turbidity

Turbidity Sensor is used to measure turbidity of water observed. This measurement is conducted by comparing the value of the measuring instrument Turbidity Meter and turbidity sensor.

The testing procedure: Pouring water into the jar; pouring mud powder into water and stir until the salt dissolves; take measurements in Turbidity Meter and turbidity sensor; add water and repeat steps 2 and 3 until achieve turbidity water sufficient.

Based on testing, the result is in line with expectations with the smallest percentage error of 0.03%. It can be said that this turbidity sensor has a level of accuracy that is good enough that deserves to be used. Comparison of measuremet turbidity between Turbidity Meter and sensor Trubidity is shown in Table 7.

TABLE 7
Comparison of measuremet turbidity between Turbidity Meter and sensor Trubidity.

Turbidity Meter (NTU)	Sensor Turbidity (NTU)	Error
137.00	136.96	0.03%
62.70	63.33	1.00%
37.60	36.88	1.91%
23.20	22.65	2.37%
1.58	0.27	82.91%

TABLE 8
The experimental results detection of water quality for some samples.

Sample water	pH	TDS (ppm)	Turbidity (NTU)	Water temp. (°C)	Air temp. (°C)	∆ T (°C)	Output Fuzzy	Result
Tap water PENS	6.30	248	0.30	28.50	31.00	2.50	0	Good
Wells water Singosari Malang	7.10	170	0.12	25.56	26.00	0.44	0	Good
PDAM water Singosari Malang	7.40	111	0.10	23.56	25.00	1.44	0	Good
Aqua water	7.60	105	0.13	28.52	31.00	2.48	0	Good
Mountain spring water Cuban Rondo Batu	7.20	71	0.14	18.50	20.00	1.50	0	Good
Wells water an area 1 at Surabaya	6.91	229	26.24	28.38	30.00	1.62	5	Less good
Wells water an area 2 at Surabaya	6.81	322	20.31	28.13	30.00	1.87	5	Less good
Tap water PENS + Soap	8.60	402	34.31	28.31	32.00	3.69	10	Bad
The hot tap water PENS + Soap	8.80	402	34.56	57.75	32.00	25.75	10	Bad

IV. EXPERIMENTAL RESULTS AND DISCUSSION

This study has conducted tests on some types of water samples, namely: tap water, well water, tap water, aqua water and tap water mixed with soap. The test site is the city of Surabaya, Singosari Malang and Batu.

Based on the test results and analysis of some of the water samples it was found that (1). PENS tap water; Malang Singosari well water; Singosari Malang PDAM water; Aqua water; Batu mountain water detected in good condition, while (2). Wells water in the sample area 1 and area 2 in Surabaya detected in less good condition, and (3). Tap water mixed with soap and hot tap water mixed with soap detected in bad condition. Details results of some of the water samples testing is stated in Table 8.

V. CONCLUSION

In accordance with the experimental data results with respect to this system can be concluded:

- On the basis of the results of the comparison between the calibrated measuring devices and sensors used in this study, it can be said that the water temperature sensor, pH, TDS, turbidity have a pretty good precision to be used in the detection of water quality.
- Water quality is good for water from the local government water company of Surabaya and Malang; mountain spring water, wells water in Malang; and aqua water. Water quality is less good for wells water in Surabaya. While poor water quality for tap water mixed with soap.

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