Smart System-Based Water Quality Measuring Device For Clean Water Availability

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ABSTRACT
Ciaruteun Ilir Village, Cibungbulang sub-district is located on the West of Bogor Regency, approximately 6 km from the sub-district capital. The village is experiencing difficulties in obtaining clean water that is suitable for consumption even though the village area has a river but is full of dirt and garbage. Even though the river is dirty, there are some people who are still using it, for example: for a bathe. There are also people who make wells, but the water quality is not guaranteed to be suitable for consumption. As a result, many people are affected by stomach and skin diseases. The monitoring systems that can observe the water quality has become an urgent need for the villagers. The results of the test produce data that is sent to an application that can be opened on the website. Both smartphone and PC can be used to obtain the data. The data then stored in the website's database and can be used to predict the water quality from time to time. Testing method of the working model of these devices and application was done through a process of repeated interaction between researchers and villagers. This technology and application are designed using devices that are connected to an android application or computer so that the users can use them both in real-time and mobile modes to monitor and make decisions about the usage of water for their health.

***Keywords**: Ciaruteun Ilir, clean water, monitoring system, water quality testing device*

1. INTRODUCTION

Ciaruteun Ilir Village is located in Bogor District area. It is bordered by Cikodom Village, Rupmin Sub-District in the north, Leuweungkolot Village in the south, Cijujung Village in the west, and Ciampea Village in the east. Ciaruteun Ilir Village, especially Poncol Village, is an underdeveloped area. Based on the results of field surveys and an interview with the head of the village, the main cause of this village's problem is that the education level of the average community (85%) is only from junior and senior high school graduates [1].

The daily needs of the people in Ciaruteun Ilir are still far from prosperous and they have some difficulties getting clean water for consumption, even though geographically, it is an area surrounded by rivers. The village area still got limited access to a clean water supply for consumption, while the geographical potential of the area is likely to get clean water because the village is crossed by a large river and some smaller ones. Although the river is still dirty because of dirt and garbage, it can still be used, since it is not the industrial waste that would make it harder to recycle. In addition to the river, this village also has 2 mountain springs which are quite good, sometimes even the people drink the water directly. The obstacle is that the location is approximately 1 km away from the village location. Currently, the water consumed by the community every day is well-water with makeshift water conditions, rainwater in reservoirs, springs, buying water or by fetching it to the spring by walking.

Those problems above leave the need for a monitoring system that can monitor water quality which is felt to be very urgent for the villagers now, for at least, the users of the water can know the quality of the water to be used and exploit it properly.

Aside from the results of interviews with village officials and the surrounding community, the latest condition of Ciaruteun Ilir Village is obtained from http://topbogor.com/warga-desa-ciaruteun-ilir-butuh-air-bersih [2]. To get clean water, the community must queue at every spring, including in the RW 09 area which was built by DPU in collaboration with PNPM KSM TARUNA NEGARA 09 BKM Mentari in 2011. This spring has never been deserted and is the main source for the villagers to get clean water for family needs, both for drinking and cooking; as well as for bathing, washing, and other toilet needs. Existing water quality conditions have never been questioned so far, so its cleanliness is unidentifiable.

From the formulation of the problem, the research questions that arise are: a) How and what is the impact of water quality problems that occur at Ciaruteun Ilir Village?; and b) How to make a water quality monitoring system based on the Smart System for the availability of clean water in Ciaruteun Ilir Village?

Based on the above conditions, the team decided to make a device that is integrated into an application to be able to know and monitor water quality before it is used or consumed by the villagers. The device is called ALUKAR (Alat Ukur Kualitas Air/Water Quality Measuring Instrument).

1.1 Related Work

Previous research serves to analyze and enrich research discussions, and distinguish them from the research being carried out, along with the State-of-the-Art Smart System for the availability of clean water in Ciaruteun Ilir Village that is used by the researchers. Here are the main research journals that are used as the main reference in conducting research, the following are the explanations.

Miftah, Erwin and Prasetya [3] are about the design of a water quality detection system using fuzzy logic. This system uses a pH sensor and an LDR that can make a water quality controller by meeting 2 of the 3 quality requirements for water that is suitable for consumption by the community. The value generated by the LDR sensor depends on how bright the room lighting is used when testing the device. The accuracy of the pH sensor reaches more than 80%. Then Fitri, Irawan, and Lindawati [4] are about the design of an Android-based water quality detection device to function as a medium to facilitate the community to conduct experiments between water that is suitable for consumption or not. The advantage of this device is that the community can avoid all diseases. After designing this device, the next step is to test the performance of the water quality detector (pH).

Reza [5], the treatment of clean water ready for drinking from WTP PNJ was suitable for consumption and passed the test from various institutions. However, with a source that is not too good, with a pH level that is too low (average 4), and a fairly high temperature (average 28oC), this WTP source needs special treatment. This treatment is intended to simplify the workings of the WTP machine so that it is more durable and has lower operating costs. Meanwhile, Ahmad, Sabriasyah and Hurriayatul [6] discussed the need to maintain good pond water quality by inserting all sensors, including pH sensor, turbidity sensor and temperature sensor, after which they were processed through an Arduino Nano microcontroller and displayed the values of all sensors mentioned on the LCD that is in the body of the system. The result of this system test shows that the system gives the value from the sensor, the pH sensor result is that if the acid solution in the water is higher, then the pH sensor value will decrease, after that the turbidity sensor result is that if the turbidity of the water is high the turbidity sensor value will be higher, and finally, the value of the temperature sensor, the hotter the water temperature, the temperature sensor on the LCD also increases.

Hidayatullah and Jauharul [7] produced a prototype of a pond water quality monitoring system that worked well by measuring parameters such as temperature, turbidity and pH using Ubidots as an interface with Arduino software. The system reads in the form of data sent to Ubidots and successfully displayed graphically in real-time. The system readings are in the form of pH 7.0 for water, 8.7 for turmeric solution and 9.0 for toothpaste solution. The system succeeds in providing readings so that the readings for the turbidity sensor are clear for plain water, turbid for turmeric and turbid solutions for toothpaste solution. Whereas the temperature readings for the three solutions have the same temperature of 21^{o}C.

1.2. Our Contribution

Research conducted by the team can meet the obstacles that occur in the above studies. Water for human life therefore, the water quality must be maintained clean. A device that uses Arduino Uno as the controller of the entire circuit, gets input from the pH sensor and the temperature sensor which will be recognized by Arduino. Then, the Arduino process will issue an output that contains Bluetooth and Android. This device will detect the pH value of water that will be consumed correctly. The team emphasized the importance of a water quality monitoring system with integrated water storage in a web-based application using the C4.5 algorithm method.

2. BACKGROUND

2.1 Research Methodology

The research methodology is a scientific process or way to obtain data that will be used for research purposes. The purpose of research, in general, is basically the same, i.e. that research reflects human desires that are always trying to find out something. The following is the research methodology conducted by the research team for the Smart System for the availability of clean water in Ciaruteun Ilir Village.

Explanation of the method carried out by the researchers is as follows:

1. Stages took in data collection
    a. Collecting data on the geographical condition of the village area of Ciaruteun Ilir Bogor through direct observation related to the condition of the water for consumption. The

purpose is to determine the condition of the water and its influence from the geographical location;

b. Reviewing through library research related to Ciaruteun Ilir village with related journals and mass media/scientific work on the water quality conditions. The purpose is to obtain an accurate reference;
c. Dig deeper information through interviews with village heads and the villagers about the condition of water quality and solutions that have been done by residents. The purpose is to synchronize and validate the results of interviews and literature review;
d. Establish identification and formulation of the problem; and
e. Establish an alternative solution to the problem.

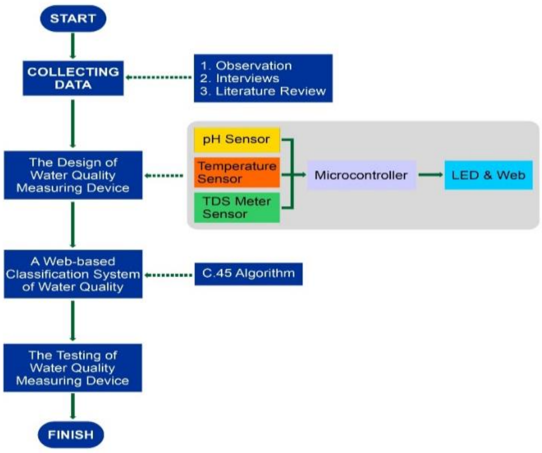

Figure 1. Research Methodology

2. Stages carried out in the design of water quality detection device
   a. System planning
   In designing this system, we can design a system with two stages of design namely hardware design and software design. The first step in designing this system is to make a hardware block diagram, then proceed with making the minimum Arduino Uno system and sensor circuits. The second step is to create software/ commands that are used to operate Arduino Uno.
   b. Hardware Design
   The hardware design consists of an Arduino control system that acts as a sensor controller and performs data processing. The design of the system is presented in the form of a block diagram that will help in designing the Android-based Water Quality Monitoring Device using Arduino Uno as a data processor, water pH sensor and LM35 temperature sensor.
   c. Software Design
   After the hardware design is complete, the next step is to design the software (command program). Software design is done using Arduino software which is then downloaded to Arduino Uno. After that, creating an android application using MIT inventor software which is then connected to the Arduino UNO software.
   d. Arduino Programming
   The making of software lines program code is done by using the Arduino idea application version 1.8.1 with a c language that is adjusted to support the overall device performance.
   e. Assemble the Dallas DS18B20 Sensor which is used to read water temperature because the Dallas DS18B20 is a waterproof sensor. This sensor consists of 3 pins namely vcc, gnd and data. The output of the DS18B20 sensor is already in digital form with a 9-bit sensor resolution. This sensor has a temperature range of -55ºC - + 125ºC. The Dallas DS18B20 can be connected to a microcontroller via one-wire interface.
   f. Assemble a pH meter; it is a scientific instrument that measures the concentration of hydrogen-ion (or pH) in a solution, showing acidity or alkalinity. The pH meter measures the difference in electrical potential between the pH electrode and the reference electrode. Usually has a glass electrode plus a calomel reference electrode, or a combination of electrodes. In addition to measuring the pH of liquids, special probes are sometimes used to measure the pH of semi-solid substances. The measuring circuit is nothing more than a voltmeter that displays measurements in pH other than volts. The input impedance measurement must be very high because of the high resistance (around 20 to 1000 ohms) on the electrode probes that are commonly used with pH meters. In the use of an analog pH meter kit, the acidity/basicity of a substance is determined based on the presence of hydrogen ions and hydroxide ions in an aqueous solution.
   g. Assemble a pH Circuit; it is a very sensitive device. This sensitivity is what gives the pH range and its accuracy. This also means that the pH circuit can read micro-voltages in the water from natural sources such as pumps, solenoid valves or other sensors. When electrical noise is mixed with pH readings, it is common to see rapidly fluctuating readings that are consistently off.
   h. Classify the water quality with data mining and the C4.5 algorithm; data mining is part of the Knowledge Discovery in Database (KDD) process. With data mining, we can classify, predict, estimate, and get other

useful information from large amounts of data collection.

i. Smart System Testing for the availability of clean water in Ciaruteun Ilir Village.

3. RESULT

The result of this study is a device called ALUKAR (Alat Ukur Kualitas Air/Water Quality Measuring Instrument) and a web application that provides and stores water quality data. Both devices and application have integrated each other.

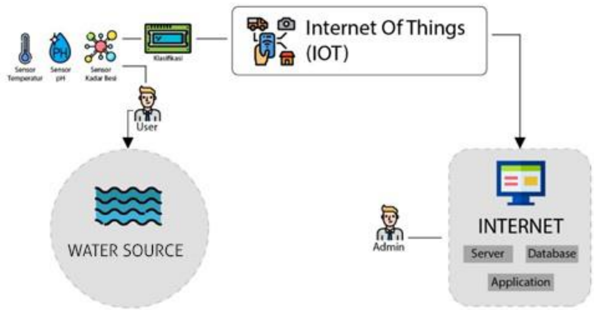

Figure 2. ALUKAR Flow Usage

3.1 Device

The method of making the device along with software and programming languages used are as follows:

Table 1. Softwares

No	Software	Usage
1	Arduino IDE	As a template for the application's development and to upload the program into the Arduino device.
2	XAMPP	As a template for web application development.
3	Sublime Text (Text Editor)	As a point to edit the source code
4	Browser	As a site to see ALUKAR's application

Table 2. Programming Languages

No	Programming Languages	Usage Areas
1	C++	Application development at Arduino
2	PHP (ver. 7.3.1)	Application development at web

3.2 How to make the device

1. All equipment is arranged according to the provisions of each component.
2. Design the program source code for temperature, pH, metal content, LCD, and GSM module sensors. Each source code is tested to ensure that each component is running well.
3. Each source program code for each sensor, LCD, and GSM module is combined into one (each sensor code is created in one function), i.e. the ALUKAR source code.
4. Design the application flow and database design. After that, creating a web application is tested whether the ALUKAR can send data to the web.

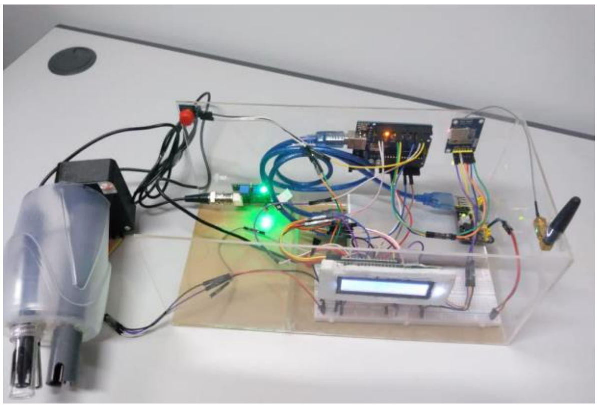

Figure 3. ALUKAR's Electronic Circuit

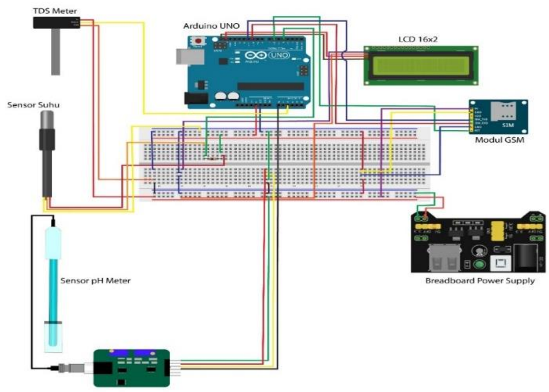

Figure 4. ALUKAR's Hardware Design

3.3 C4.5 Algorithm

C4.5 algorithm (decision tree) is a commonly used method to do the data mining classification. Classification is a procedure of finding a group of patterns or functions that express and separate a class of data from another to assert the object into a specific category by observing the behavior and attributes of the group that has been outlined. [8], [9] The steps of the system are: 1) Select dataset, input to the algorithm to be processed; 2) Select the classifiers; 3) Calculate the entropy, information gain, and gain ratio of attributes; 4) Process the given input dataset according to the defined algorithm of C4.5; 5) The data that has been inputted to the tree generation mechanism is given by the C4.5 processor; and 6) Tree generator generates the tree for C4.5 and improved C4.5 decision tree algorithm. [10]

From time to time, the data gathered – those which come from the same source but taken at different times can be concluded. The method used is the C4.5 algorithm. The case study can be seen from the following table:

Table 3. C4.5 Algorithm from ALUKAR

No	pH	Temp.	TDS	Result
1	Normal	Normal	Suggested	Feasible
2	Alkaline	Normal	Not Suggested	Not Feasible
3	Normal	Normal	Suggested	Feasible
4	Normal	Warm	Suggested	Less Feasible
5	Normal	Normal	Suggested	Feasible
6	Normal	Normal	Not Suggested	Not Feasible
7	Alkaline	Mild	Suggested	Feasible
8	Normal	Normal	Suggested	Feasible
9	Normal	Normal	Suggested	Feasible
10	Normal	Normal	Suggested	Feasible
11	Normal	Normal	Suggested	Feasible
12	Acid	Normal	Suggested	Feasible
13	Alkaline	Normal	Suggested	Less Feasible
14	Alkaline	Normal	Suggested	Less Feasible
15	Normal	Normal	Suggested	Feasible
16	Alkaline	Normal	Suggested	Less Feasible
17	Alkaline	Normal	Suggested	Not Feasible
18	Normal	Warm	Suggested	Less Feasible
19	Normal	Normal	Suggested	Feasible
20	Normal	Warm	Suggested	Less Feasible
21	Normal	Warm	Not Suggested	Not Feasible
22	Normal	Warm	Suggested	Feasible
23	Alkaline	Normal	Not Suggested	Not Feasible
24	Normal	Warm	Suggested	Feasible
25	Alkaline	Warm	Suggested	Not Feasible
26	Normal	Normal	Suggested	Feasible
27	Acid	Normal	Suggested	Less Feasible
28	Alkaline	Warm	Suggested	Not Feasible
29	Normal	Warm	Suggested	Less Feasible
30	Normal	Normal	Suggested	Feasible
31	Normal	Warm	Suggested	Feasible
32	Alkaline	Normal	Suggested	Less Feasible

A decision tree will be made based on the cases from the table above to determine the feasibility of the water sample by considering its pH, temperature, and Total Dissolved Solids (TDS).

Table 4. Entrophy Calculation

		Tot.	F	LF	NF	Entrophy	Gain
Tot.		32	16	9	7	1,494349704	
pH							0,3460612
	Acid	2	1	1	0	0	
	Normal	20	14	4	2	1,156779649	
	Alkaline	10	1	4	5	1,360964047	
Temp							0,0781315
	Mild	1	1	0	0	0	
	Normal	21	12	5	4	1,409975019	
	Warm	10	3	4	3	1,570950594	
	Hot	0	0	0	0	0	
Number of TDS							1,3292181
	Suggested	28	16	9	3	0,188721876	
	Not Suggested	4	0	0	4	0	

Note: F=Feasible; LF=Less Feasible; NF=Not Feasible

The solving steps are as follows:

a. Calculating the number of cases (for feasible, less feasible, and not feasible decisions) and entropy for all the cases which then divided based on the pH, temperature, and TDS attributes.

$$Entropy(Total) = \left(-\frac{16}{32} * \log_2\left(\frac{16}{32}\right)\right) + \left(-\frac{9}{32} * \log_2\left(\frac{9}{32}\right)\right) + \left(-\frac{7}{32} * \log_2\left(\frac{7}{32}\right)\right)$$
$$= 1{,}494349704$$

b. Calculating the *Gain* for each attribute.

The *Gain* value on the pH row is calculated with the following equation:

$$= Entropy(Total) - \sum_{i=1}^{n} \frac{|pH|}{|Total|} * Entropy(pH)$$

$$= 1{,}494349704 - \left(\left(\frac{2}{32} * 0\right) + \left(\frac{20}{32} * 1{,}156\right) + \left(\frac{10}{32} * 1{,}360\right)\right)$$
$$= 0{,}3460612$$

From the table above, it can be understood that the attribute with the highest Gain is the TDS with 1,32. So the TDS will be the root node. There is 2 attribute values from JPT, i.e. suggested and not suggested, though we need to count the suggested value only.

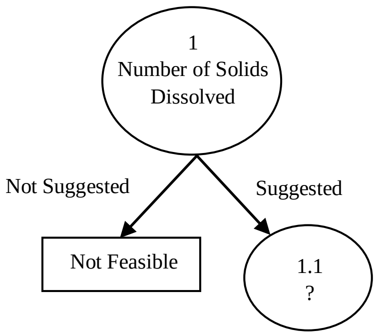

Figure 5. Decision Tree Node 1

Then do the calculation to find the Node 1.1

Table 5. Node 1.1 Calculation

		Tot.	F	LF	NF	Entrophy	Gain
Tot.		32	16	9	7	1,494349	
pH							1,1429399
	Acid	2	1	1	0	0	
	Normal	17	13	4	0	0	
	Alkaline	8	1	4	3	1,4056390	
Temp							0,4444147
	Mild	1	1	0	0	0	
	Normal	17	11	5	1	1,166087	
	Warm	9	3	4	2	1,530493	
	Hot	0	0	0	0	0	

Note: F=Feasible; LF=Less Feasible; NF=Not Feasible

From the table above, it can be understood that the attribute with the highest *Gain* is pH, with 1,14. So then pH will be the branch node from the suggested attribute.

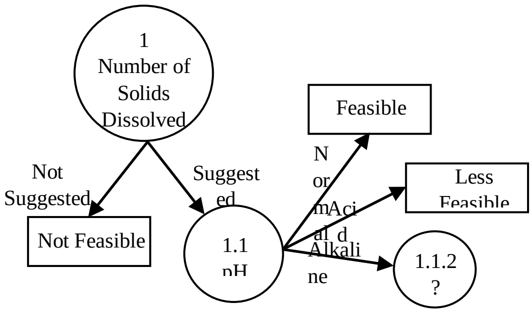

Figure 6. Decision Tree Node 1.1

Then do the calculation to find the Node 1.1.2

Table 6. Node 1.1.2 Calculation

		Tot	F	LF	NF	Entrophy	Gain
Tot.		32	16	9	7	1,4943497	
Temp							1,3815484
	Mild	1	1	0	0	0	
	Normal	5	0	4	1	0,721928	
	Warm	2	0	0	2	0	
	Hot	0	0	0	0	0	

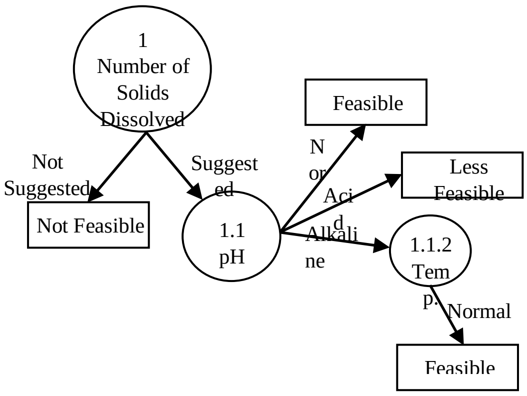

Figure 7. Decision Tree Node 1.1.2

3.4. The Result of the test

The results of the test produce data as shown in the table below:

Table 7. ALUKAR's Device Test

No	Test	Test Case	Result	Summary
1	Turn on the device	User connecting the device to the Power Bank	The device is on	Valid
2	Show the sensor's measurement data	User put the sensor to the tested water	The data is presented on the LCD measurement data	Valid

Table 8. Connection test between the device & cell phone

No	Test	Test Case	Result	Summary
1	Send the data to the web server	User insert the SIM card, turn on ALUKAR and put the sensor to the water	The device is on, then the data appears on the cell phone	Valid
		User insert the SIM card, turn on ALUKAR and does not put the sensor to the water	The device is on, then the data appears as 0	Valid

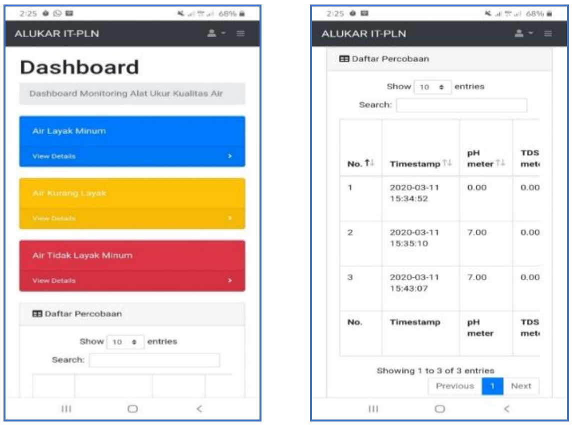

Figure 8. ALUKAR Data Display on the cell phone

Table 9. Connection test between the device and the web

No	Test	Test Case	Result	Summary
1	Device is ready to send the data	User insert a low connectivity SIM card, then turn on ALUKAR	The Device is on but continuously searching for signal	Valid
		User insert a high connectivity SIM card, then turn on ALUKAR	The Device is on and the GSM module is connected to the network	Valid
2	Send the data to the webserver	User insert the SIM card, turn on ALUKAR and put the sensor to the water	The Device is on then the data appear on the web every programmed time intervals	Valid
		User insert the SIM card, turn on ALUKAR and does not put the sensor to the water	The device is on, then the data appears as 0	Valid
		User does not insert the SIM card, turn on ALUKAR and does not put the sensor to the water	The device is on, but there is no data on the website	Valid

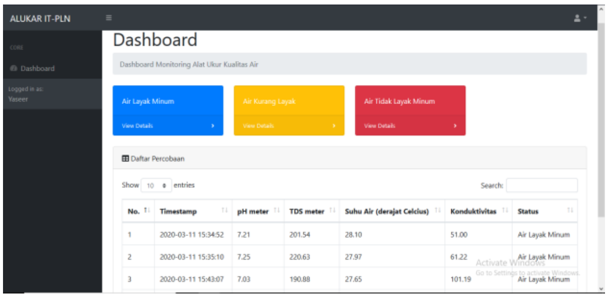

Figure 9. ALUKAR's Data Display on the web

4. CONCLUSION

From the process of making and testing ALUKAR (Alat Ukur Kualitas Air/Water Quality Measuring Instrument) above, it can be concluded that:

1. ALUKAR is designed using a combination method of making prototype technology device and application, and then classified using the C4.5 algorithm. In order to determine the feasibility of the water, we consider 3 elements, i.e. pH, temperature, and Total Dissolved Solids (TDS). Based on the calculation, we have the highest Gain is the TDS with 1,32 as the root node, the attribute of the pH is 1,14 and temperature is 1,38. Those numbers are used as a basis to decide the feasibility of the water
2. ALUKAR can be a solution for the community to be able to know the quality of the water they will use.
3. ALUKAR with its web database system can predict water quality in certain seasons or times in an area.
4. ALUKAR is portable, so it can reach remote water sources with a high degree of accuracy.
5. The development of ALUKAR can be done by adding several other water quality inspection features, such as: mineral content, chemical content, etc. and by adding water quality matches with their usages on the web.

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