

Performance Analysis of a Multisensor IoT System for Water Quality Surveillance at PDAM Makassar

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Published: November , 2025

ABSTRACT

This study presents an IoT-based water quality monitoring system for Makassar City PDAM, using pH, TDS, and NTU sensors to assess water quality in real-time. The data is displayed via a web application in graphical form, enabling easy monitoring by PDAM staff. Water is considered in proper condition if the pH is 6.5-8.5, TDS is 0-300 ppm, and NTU is 0-25. The system achieves an overall accuracy of 91.25%, with individual sensor accuracies of 94.74% for pH, 93.70% for TDS, and 85.31% for turbidity. The key innovation lies in integrating multiple sensors and providing real-time, accessible water quality data through a web platform.

Keywords: *Monitoring System, Water Quality, Sensor, IoT, PDAM.*

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INTRODUCTION

Communities in Indonesia are still faced with several problems that are quite complex and until now still cannot be fully overcome. One of the problems faced is the low level of clean water services for the community. The provision of clean water for the community has a very important role in improving environmental or community health, and plays a role in improving the standard or quality of life of the community. Water is the primary source of life for humans. The utilization of water as a primary need makes water the highest level of need (Ardiansyah. 2016). The water needed is of course clean and healthy water that has been determined as water that is suitable for consumption. Water suitable for consumption must meet physical requirements, the water must be clear or not cloudy. Turbidity in water is usually caused by the presence of silt particles. Colored water means that it contains other materials harmful to health.. Water that tastes sour or salty indicates that the quality of the water is not good, salty taste is due to the presence of certain salts that dissolve in water. While the sour taste is caused by the presence of organic and inorganic acids, the degree of acidity (pH) is neutral around 6.5 - 8.5 water with a low pH will taste sour while when the pH is high it feels bitter, foul-smelling water contains organic materials that are being decomposed (decomposed) by water microorganisms, water temperature between 10-25 C (Chen et al, 2021).

In this study we chose PDAM water because it is the main water in the fulfillment of daily raw water for household drinking water, where the quality of water consumed daily must meet the feasibility as determined by the Ministry of Health (Permenkes number: 416/men.kes/per/ix/1990). The development of drinking water systems is the responsibility of the government and / or local governments through State-Owned Enterprises (BUMN) or Regional-Owned Enterprises (BUMD), as implied in Article 40 paragraph (3) of Law Number 7 of 2004 concerning Water Resources Management (Permenkes, 1990). With the development of the water supply system, the main objective to be achieved is the management and management of quality drinking water at affordable

prices for all levels of society, therefore the Makassar City Regional Drinking Water Company (PDAM) is given the authority to handle and manage water suitable for consumption for the needs of the people in Makassar City.

The source of water for Makassar City PDAM is the Jeneberang River flow, by taking samples of Jeneberang River water before entering the PDAM inlet then taken to the Laboratory shows the results in general the quality of Jeneberang river (Muh Fadjrin Mubarak et al. 2016). water as raw water for Makassar City PDAM is still feasible according to government regulations (Permenkes, 1990). By taking 199 Makassar City PDAM customer water samples in 2014, it was concluded that the physical and chemical quality of clean water in Makassar city was still good and had met the requirements even though there were still family heads who still experienced physical water quality problems (Doni Purowo et al, 2014). From the two research results above, it shows that the quality of raw water sources and water that has been received by PDAM customers has met the eligibility standards in the 2014-2016 period so that research is needed again with more effective methods and technology for the condition of the feasibility of PDAM Makassar City consumption water and supervision of the Makassar City PDAM Inlet effectively without having to conduct laboratory tests, this research is needed because over time human behavior and the natural conditions of the Jeneberang River will change due to population density and natural climate change.

The development of technology is very rapid at this time, one of which is technology in the field of microcontrollers. Namely, ATmega, an open-source single-board microcontroller. ATmega technology is used in Arduino, which is designed to help users in the field of electronics.. The programming language used is C / C ++, in an ATmega microcontroller can also be embedded various libraries and methods as long as the memory capacity of a microcontroller is sufficient (Ibrahim et al. 2024). The combination of using the ATmega328 microcontroller and Photodiode *array* arranged in parallel successfully shows the difference in water turbidity levels through LEDs with an average measurement *error* margin of 2.9% (Matic et al, 2021). With the presence of the above technology, a tool will be designed to check the condition of water suitable for consumption so that PDAM water flowing to the community can be consumed and has met good pH standards for consumption (Ahmed, S Khan. 2021). With this system, it is hoped that it will be able to overcome the problems that exist in the community today, namely regarding information on water suitable for consumption from the Regional Drinking Water Company and meeting the eligibility standards of the Ministry of Health.

Despite progress in water quality monitoring, PDAM staff still lack real-time, high-accuracy monitoring, especially for multisensor systems. Existing approaches, often involving lab testing, are not necessarily practical for real-time monitoring. Despite research indicating that raw water sources and Makassar PDAM-distributed water meet health standards, they do not address the demand for a more effective, real-time monitoring solution to ensure water quality. The wireless multisensor system for signal propagation in IoT has been explored as a viable solution to this problem, enabling continuous online data access across a variety of environmental conditions and control via integrated pH, TDS, and NTU sensors. However, there is little work on how these systems could be used at the local level by PDAM staff with acceptable accuracy and ease of use. Filling this gap between the tools can dramatically improve water quality management and public trust by providing accurate, real-time water quality information that is easy to access.

1.1 Problem Formulation

Based on the background described above, the problem formulation in making this application is as follows:

1. How to design and create an application for monitoring water suitable for consumption using Internet of Things Technology?
2. How to know the level of water quality worthy of consumption in *real time* compared to data from Makassar City PDAM officers?

1.2 Research Objectives

1. The objectives of this research are as follows. Design and build an application to monitor water for consumption, using Internet of Things Technology.
2. Analyze the accuracy of the water quality monitoring system.

1.3 Research Methods

1.3.1 Block Diagram

The block diagram is used to simplify the hardware design, the block diagram displays the components used and the connections between the components. The block diagram is shown I Figure 1. Below:

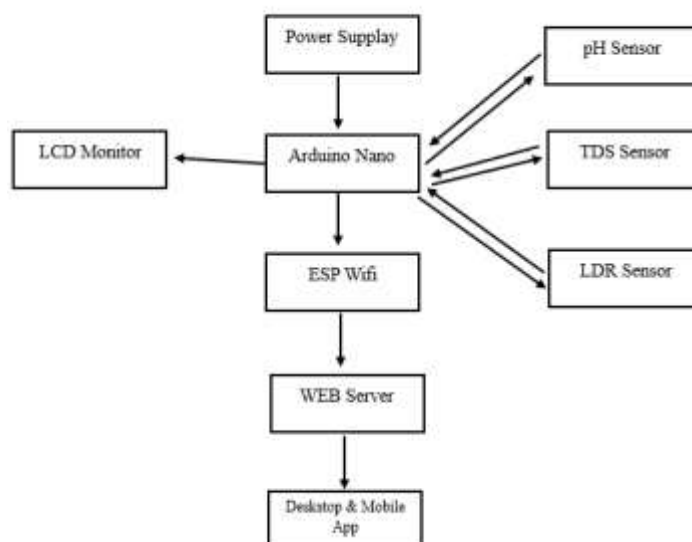


Figure 1. Block Diagram

As shown in the picture above, the Internet of Things-based Water Monitoring System consists of several inputs and outputs. The primary *power* source is a *power supply/adapter* with a 12-volt output. The main module is the Arduino Nano microcontroller. This microcontroller will process input data and provide output. The inputs to this system are data from the water pH sensor, a detector of water acidity; the TDS sensor, a detector of PPM levels; and the LDR sensor, a detector of water turbidity in the reservoir.. The output for monitoring the condition of the water in the reservoir is using a website with transfer media using WIFI.

1.3.2 Monitoring System Design

The following is the design of the monitoring system. Can be seen in the picture below:

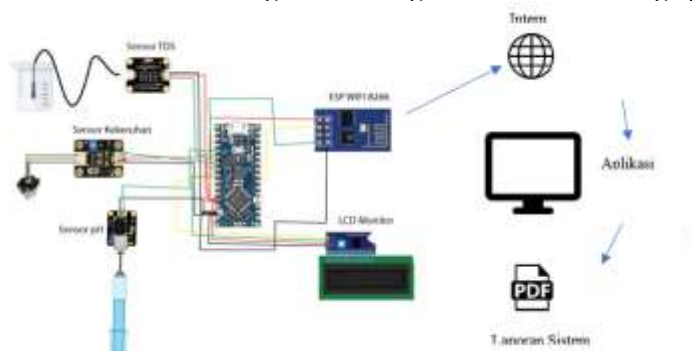


Figure 2. Monitoring System Design

From the illustration, it's clear that the water pH sensor, TDS sensor, and LDR sensor each have a specific function in the water monitoring system. The data from these sensors is then efficiently processed by the Arduino. The results of this processing are then swiftly transmitted to the web server via the ESP-WiFi 8266, a tool that ensures the data is promptly displayed in the website application. the data entered in the website application can be exported in the form of a PDF report (Chen et al. 2023).

RESULTS AND DISCUSSION

The results of this study can be described as follows:

2.1 Problem solving

From the researcher's observation of the existing problems, an alternative is obtained to monitor water with a pH sensor, TDS sensor and LDR sensor then controlled using Arduino Uno, the data taken by the sensor is forwarded to the web server using ESP Wifi 8266 by matching the network protocol so that data can be displayed in *real time* on the website application (Garcia et al. 2022).

2.2 Implementation

In this research, the tool is designed from various components assembled and connected to one another. Below are the hardware components and software applications that researchers use in realizing this research.

2.2.1 Hardware

The hardware used to develop and test is divided into several parts, among others:

- a. Asus laptop with AMD Ryzen 5 Processor specifications 500 GB Harddisk, 4 GB Memory.
- b. ATmega826 in Arduino nano module
- c. ESPWIFI 8266
- d. pH Sensor
- e. TDS Sensor
- f. Turbidity Sensor
- g. 12 Volt power supply.

2.2.2 Software

The software used in this application is as follows:

- a. Windows 10 64 bit operating system.
- b. Arduino IDE software
- c. PHP-based web server
- d. Chrome Browser

2.3 Test Results

2.3.1 Overall Tool Set

The following is a display of the monitoring tool assembled from several components, Arduino Uno as the brain of all the data reading processes from all sensors which are then forwarded to the web server using ESP Wifi 8266:



Figure 3. *Overall Tool Set*

In this monitoring system tool, all components are assembled on a circuit board starting from the power supply, pH sensor, TDS sensor, turbidity sensor, WIFI ESP8266, and LCD monitor where all these devices are centered on the ATmega328 installed on the Arduino Nano module (Kumar. 2023).

2.3.2 Data Analysis

We collected data through sensors using a monitoring system developed in the Makassar City PDAM laboratory over a period of two weeks. The data was then compared with water quality measurements taken manually by Makassar City PDAM officials using laboratory equipment. The results of the comparison are as follows

the calculation of the Turbidity value shows that the value of the monitoring system data has an average margin of error of 14.69%, the pH value has an average margin of error of 5.26%, while the TDS value has an average margin of error of 6.30% To get the margin of error, the following equation is used:

$$\text{Margin error value} = | \text{Turbidity value of PDAM Officers} - \text{Turbidity value of the Monitoring System} |$$

Then

$$\text{Percentage value of error margin: error value} / \text{turbidity value of PDAM staff} \times 100$$

(1)

The following are the results of the calculation of the *margin of error* of the monitoring system that researchers conducted on data taken manually by PDAM Makassar City employees:

Table 1. Accuracy rate results

No.	Parameters	Accuracy Level
1	Turbidity	Turbidity Accuracy = 100% - 14.69% = 85.31%
2	pH	pH accuracy = 100% - 5.26% = 94.74%
3	TDS	TDS Accuracy = 100% - 6.30% = 93.70%
	Total Accuracy Level	91,25 %

In Table 1 is the result of comparing data from Makassar City PDAM officers with data from the water monitoring system worthy of consumption in the calculation Turbidity value shows that the value of monitoring system data has an accuracy rate of 85.31%, the pH value has an accuracy rate of 94.74%, while the TDS value has an accuracy rate of 93.70% To get the level of accuracy the following Equation is used:

$$\text{Accuracy Value} = 100\% - (\text{average error})$$

then

$$\text{Total accuracy score} = \text{Number of accuracy scores} / 3$$

The lower precision of the turbidity sensor, error of 14.69%, could be due to a number of reasons. Turbidity measurements are based on light scattering of particulate suspended in water, and alterations in particle size, form and concentration can result in concerning sensor output. Moreover, turbidity sensors are susceptible to environmental fail factors such as temperature fluctuation, interference of light and aging of sensors which would degrade the performance of them. There may be also calibration concerns, particularly if the sensor hasn't been properly calibrated for the specific water you're testing. These combined effects sensor sensitivity, external factors and limitations of data processing diminish the precision of the obtained turbidity readings within the system. Sensors' Precision The pH sensor showed the best precision, with an error rate of 5.26%, implying that its accuracy was 94.74%. The accuracy of the TDS sensor was 93.70% with margin of error is 6.30%. The accuracy of the turbidity sensor was less than the e-nose 85.31%±1.414; sometimes it failed with 14.689%±0.71 error rate. These findings indicate that the pH and TDS sensors are very reliable, while the turbidity sensor has to be optimized for a better accuracy.

Comparison to Manual Measurement: The data of IoT-base monitoring system was compared to the manual measurement conducted by officers of PDAM Makassar. The results revealed that the readings obtained through monitoring system were in good agreement with manual measurement values, which verified the success of the IoT based method for real-time water

quality analysis. The turbidity data, however, were comparatively more erroneous and indicated a need for further sensor calibration and accuracy.

For Accuracy Overall system accuracy was estimated to be 91.25%, signifying a health level of precision for determining the correctness of water quality data for drinking purposes. This high accuracy is particularly important for the pH and TDS sensors, which are used to estimate water potability. As for the labor and time efficiency, the developed monitoring system provided better performance than traditional manual methods. This is especially important in view of the fact that real-time web application data accessibility not only facilitates decision making, but also minimizes the repetitive testing burden on physical measurement which is time and labor intensive.

CONCLUSION

In this study, the following conclusions can be drawn:

1. This system can monitor water in realtime.
2. Both methods of collecting water feasibility data show that Makassar City PDAM Water is declared "Feasible" for consumption.
3. The Turbidity value shows that the monitoring system data value has an accuracy rate of 85.31%, the pH value has an accuracy rate of 94.74%, while the TDS value has an accuracy rate of 93.70%, so it can be concluded that the overall accuracy rate of this system is 91.25%.
4. With the level of data accuracy on each parameter in this research, it can be concluded that for the use of TDS and pH sensors, water has a high level of accuracy so that it can be a recommendation in monitoring water feasibility, while the turbidity sensor has a poor level of accuracy.
5. With this monitoring system method, the efficiency of labor and time required is better than the Makassar City PDAM monitoring system method.

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