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UTILIZING TOTAL DISSOLVED SOLIDS (TDS) SENSOR FOR DISSOLVED SOLIDS MEASUREMENT IN THE WATER

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ABSTRAK

Air bersih sangat penting untuk menopang kehidupan, tetapi semakin terancam oleh faktor-faktor seperti pertumbuhan populasi dan industrialisasi, yang menyebabkan polusi yang signifikan. Memantau kualitas air, termasuk Total Padatan Terlarut (TDS), sangat penting untuk memastikan standar kesehatan. TDS mewakili zat terlarut dalam air, yang memengaruhi rasa, keamanan, dan kegunaan. Kemajuan sensor terbaru, khususnya sensor TDS, menawarkan pemantauan waktu nyata dan hemat biaya. Penelitian ini mengevaluasi efektivitas sensor TDS dalam mengukur padatan terlarut, yang bertujuan untuk meningkatkan metode pemantauan kualitas air. Hasil penelitian menunjukkan bahwa sensor TDS secara akurat membedakan air bersih dan air kotor, dengan rata-rata kesalahan 0,008894%. Penelitian di masa depan harus menguji keandalan sensor dalam berbagai kondisi dan meningkatkan teknologinya. Pengujian kualitas air berdasarkan pengukuran padatan terlarut dalam satuan part per million (PPM) menunjukkan bahwa 7 dari 12 sampel memenuhi kriteria air bersih, sementara yang lainnya dikategorikan sebagai air kotor.

Kata kunci: Sensor Padatan Terlarut Total, Pemantauan kualitas air, Kelestarian lingkungan

ABSTRACT

Although industrialization and population growth seriously threaten clean water, which is necessary for life, they also cause significant pollution. Monitoring water quality, including Total Dissolved Solids (TDS), ensures health standards. TDS represents dissolved substances in water, affecting taste, safety, and usability. Recent sensor advancements, particularly TDS sensors, offer real-time, cost-effective monitoring. This study evaluates the effectiveness of the TDS sensor in measuring dissolved solids, aiming to improve water quality monitoring methods. Results show that TDS sensors accurately distinguish between clean and dirty water, with an average error of 0.008894%. Future research should test sensor reliability in various conditions and enhance its technology. Water quality testing based on dissolved solids measurements in parts per million (PPM) indicates that 7 out of 12 samples meet clean water criteria, while others are dirty.

Keywords: Total Dissolved Solids sensor, Water quality monitoring, Environmental sustainability

INTRODUCTION

The necessity of clean water for human, animal, and plant life is indisputable. However, this vital resource is under increasing threat due to rapid population growth, urbanization, industrialization, and climate change (Dwicahyo et al., 2022). Human activities, such as industrial and household waste, as well as pesticide use in agriculture, have led to significant water pollution (Nugraha, 2018). This situation not only endangers human health and disrupts ecosystem balance but also triggers social and economic issues, underscoring the urgency of our research (Anshori et al., 2022).

According to the World Health Organization (WHO), approximately 1.8 billion people worldwide use drinking water sources contaminated by faces, leading to over 840,000 deaths annually from waterborne diseases. In Indonesia, this issue is a significant concern for the government. A report from the Ministry of Environment and Forestry reveals that a staggering 68% of rivers in the country are heavily polluted. To address this, the government is actively developing effective, efficient, and environmentally friendly water purification technologies, making our research highly relevant (Ariyanti & Widiasa, 2011).

Natural water purification technologies, such as filtration with natural materials, offer a sustainable solution with minimal negative environmental impact (Nugraha & Arifuddin, 2020). Natural materials such as activated charcoal, zeolite, and certain aquatic plants have been proven to filter and absorb pollutants in water effectively. In addition to purification technology, regular water quality monitoring is also essential to ensure that the water consumed meets the government's health standards and quality standards (Bu'u et al., 2023). This monitoring involves measuring specific parameters, such as pH, turbidity, and Total Dissolved Solids (TDS). However, conventional monitoring processes often require significant time and cost and are prone to human error in data interpretation (Akhmad et al., 2021).

Total Dissolved Solids (TDS) is a crucial parameter for assessing water quality, representing the total concentration of dissolved substances in water, including minerals, salts, and organic matter (Priyatman et al., 2022). High levels of TDS in water can affect the taste, health, safety, and suitability of water for various uses. Therefore, monitoring TDS levels is essential for effective water quality management. Recent advances in sensor technology have enabled real-time measurement of TDS levels using TDS sensors (Anwar et al., 2021). These sensors offer several advantages: real-time monitoring, cost efficiency, portability and ease of use (Chuzaini et al., 2022).

This study aims to evaluate the effectiveness of TDS sensors in measuring dissolved solids in water. The specific goals were to determine how accurate and reliable TDS sensors are compared to traditional lab methods, how TDS levels change over time and space in specific river systems, and how these changes might affect the environment and people's health (Setiawan & Munadhif, 2021). By achieving these objectives, this research aims to contribute to the development of efficient and reliable methods for water quality monitoring, thereby supporting efforts to protect and manage vital water resources (Anggara Trisna Nugraha & Priyambodo, 2020). Overall, integrating TDS sensors in water quality monitoring programs promises to improve our ability to safeguard river ecosystems and public health (Hardianto Dwiko & Aryawan Dwi Wasis, 2017). This research provides a basic assessment of the usefulness and effectiveness of TDS sensors in measuring dissolved solids in water.

Materials and Method

This section will discuss the main literature review that supports this article, along with the research methods used.

Research Methods

Many previous studies have examined the importance of water quality monitoring, which is measuring and evaluating specific parameters in water to determine the feasibility and class of water quality standards under applicable regulations. One parameter often measured is Total Dissolved Solids (TDS), which refers to the number of solids dissolved in water, including ions, compounds, or colloids. High TDS often comes from agricultural activities, household waste disposal, and industrial processes. Chemical elements typically contained in TDS include calcium, phosphate, nitrate, sodium, potassium, mercury, lead, and chloride. The study conducted by Anwar et al. (2021) confirmed that the presence of these substances in high amounts can cause various environmental and health problems, so regular monitoring and proper management are essential to ensure water quality remains within safe limits and follows established quality standards (Anwar et al., 2021).

Research by Anwar et al. (2021) also showed that variations in TDS concentration can indicate the source of pollution and potential risks faced by aquatic ecosystems and human populations that rely on these water sources. Thus, the importance of monitoring TDS parameters in water quality management cannot be ignored, as this information not only helps in determining water quality status but also in decision-making for remediation and environmental protection measures.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) are smaller particles than suspended solids. Although dissolved materials in natural waters are generally non-toxic, excessive amounts can increase water turbidity, inhibit sunlight penetration, and interfere with photosynthesis in the water (Oktaviana et al., 2022).

High levels of TDS, if not appropriately managed, can pollute water bodies, harm aquatic life, and negatively impact human health due to high concentrations of chemicals such as phosphates, surfactants, ammonia, and nitrogen, as well as suspended and dissolved solids (Bu'u et al., 2023) .

ESP32

Expressive Systems introduced the ESP 32 microcontroller as the replacement for the ESP 8266 microcontroller(Purwantoro et al., 2019). It has many advantages compared to other microcontrollers, including more pins, more analogue pins, a larger memory capacity, and Bluetooth 4.0 Low Energy and WiFi support. These features allow the ESP 32 to be used in various IoT (Internet of Things) applications (Novita Wardhani et al., 2022).

Figure 1. ESP32 microcontroller

The ESP32 is designed for use in mobile applications, electronic devices, and the Internet of Things (IoT). The ESP32 microcontroller can operate at low power and utilizes a low-duty cycle to minimize chip energy consumption. As an integrated microcontroller, the ESP32 supports Wi-Fi and Bluetooth IoT and comes with 20 external components (Yusril Maulana et al., 2022).

Total Dissolved Solids Sensor

The TDS sensor is an electronic device that has the ability to measure the concentration of solids dissolved in water using analog signals. By utilizing advanced technology, this sensor is able to provide information about the number of dissolved particles in water with high precision (SETIAWAN et al., 2019). The measurements produced by TDS sensors are generally expressed in units of parts per million (ppm), which indicates the number of dissolved particles per million parts of water.

The use of TDS sensors is widespread in various fields, including agriculture, industry, and environmental management. In agriculture, TDS sensors are used to monitor the quality of irrigation water and plant nutrient solutions, allowing farmers to optimize plant growth by providing appropriate nutrients (Sebastian et al., 2021). In the industrial sector, TDS sensors play an important role in controlling the production process and ensuring the quality of the products produced. Additionally, in environmental management, TDS sensors are used to monitor the water quality of rivers, lakes or seas, as well as to detect potential water pollution or contamination (Febrianti et al., 2021).

Figure 2. Total Dissolved Solids Sensor

TDS sensors have the ability to detect various chemical compounds that dissolve in water, such as calcium, phosphate, sodium, potassium, and so on. The information provided by these sensors is valuable in maintaining environmental balance and human health, as high concentrations of certain substances in water can negatively impact aquatic ecosystems and human health.

Hardware Design

Hardware design is the process of designing and developing the physical components of an electronic system or hardware. It involves the selection and integration of various elements such as electronic circuits, sensors, actuators, microcontrollers, and other components to create a solution that fits the specific needs of an application.

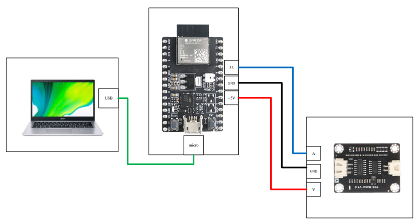

Figure 3. Hardware Design

Figure 3 shows the wiring schematic plan for the TDS sensor and ESP32. There are 3 pins that connect between the two. The first pin in blue is connected to the ESP32 with the GPIO33 pin, the second pin marked in red is VCC connected to Vin 5V on ESP32, and the third pin in black is connected to GND or ground on ESP32.

Flowchart Design

A description of a hardware system's work refers to the part that explains the system's operational process. To help understand how the system operates as a whole, a flowchart is often created that illustrates the sequence of steps. Below is a flowchart detailing the system's working principles from start to finish. It is a diagrammatic representation of the system's working steps.

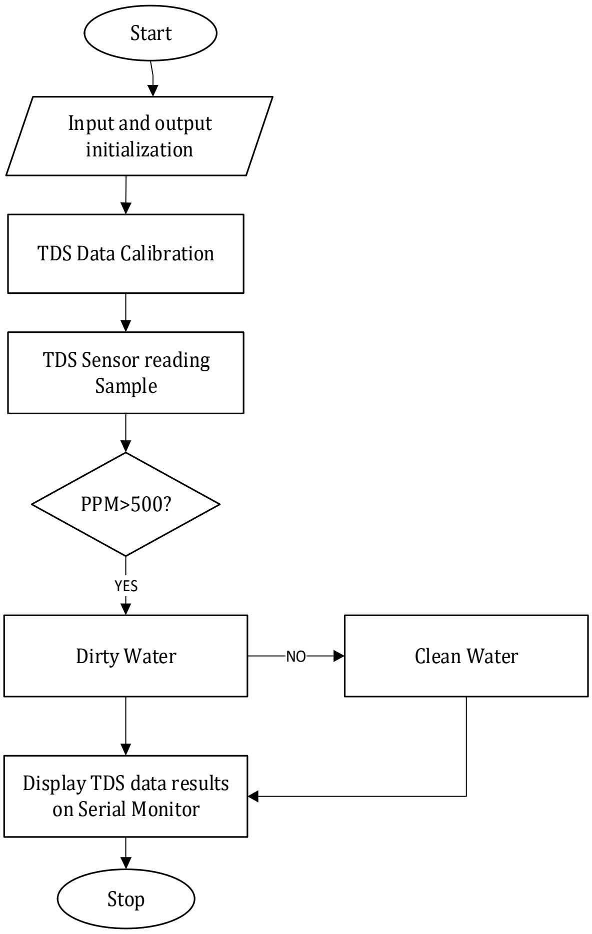

Figure 4. Flowchart design

In Figure 7, there is a system flow chart that illustrates its operational process. The system is designed for ease of use, starting with input and output initialization, followed by calibration of the TDS sensor to ensure the accuracy of the reading. After that, the sensor reads the water sample, and if the PPM value exceeds 500, the water is classified as dirty; whereas if the PPM value is less than 500, the water is considered clean. The reading results are conveniently displayed on the laptop's serial monitor, making it easy and comfortable for the user to monitor the quality of the tested water. After the display of the results, the system will stop, completing the testing process. Thus, this system provides convenience in monitoring and classifying water quality based on measured PPM values.

RESULT AND DISCUSSION

Sensor Testing

Testing the sensor involves a detailed process of calibrating the TDS sensor using the provided calibration fluid. The calibration was meticulously performed in this experiment using two different comparison liquids. The voltage output from the sensor served as the basis for measuring and evaluating these liquids.

Figure 5. Calibration Liquids

This multi-step calibration process is crucial to ensure that the sensor delivers precise and accurate measurement values. Without proper calibration, the sensor's readings could be significantly off, leading to incorrect conclusions about water quality. The picture showcases the clean water quality measuring device that has been successfully constructed.

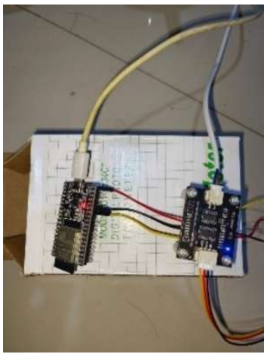

Figure 6. Total Dissolved Solids Device

This device was rigorously tested and compared with standard measuring instruments to validate its accuracy and reliability. Such thorough calibration and testing procedures underscore the importance of precision in developing instruments meant for environmental monitoring. By ensuring high accuracy, the device can provide trustworthy data on water quality, which is essential for maintaining public health and safety. This demonstrates the successful integration of robust engineering practices with environmental science, resulting in a reliable tool for assessing water cleanliness.

Figure 7. The device and compared with standard measuring instruments.

The operation of this clean water quality measuring device starts with connecting the ESP32 data cable to a laptop or computer to supply voltage to the device. Next, the sensor is placed in a prepared plastic container. When the TDS sensor measures the level of total dissolved solids in the water and records a value greater than 500 PPM, the device categorizes the water as dirty. Conversely, the water is categorized as clean if the dissolved solids value is less than 500 PPM. The measurement results, including the PPM value and the water category, whether clean or dirty, are then displayed on the Serial Monitor. This setup ensures accurate real-time monitoring and categorization of water quality, making it a reliable tool for assessing water cleanliness. The device's ability to provide immediate feedback on water quality is crucial for various applications, including environmental monitoring and public health safety.

The following table shows the calibration results of the TDS sensor. In this experiment, two types of water were used: unbranded mineral and pond water. The table presents the measurement results obtained from the TDS sensor after calibration. These results give an idea of the level of total dissolved solids (PPM) in both types of water and confirm that the sensor is functioning with the required accuracy. Here are the calibration results:

Table 1. Calibration Results

Water Type	Time (Minute)	TDS meter (ppm)	TDS Sensor (ppm)	Error (%)	Average Error (%)
Mineral Water	1	283.81	228	0.20	0.18
		288.99	228	0.21	
		287.7	257	0.11	
		288.99	228	0.21	
		277.34	228	0.18	
		268.28	228	0.15	
	2	255.34	228	0.11	0.06
		247.58	265	0.07	
		237.22	265	0.12	
		222.99	228	0.02	
		225.57	228	0.01	
		222.99	218	0.02	
	3	226.87	218	0.04	0.17
		285.11	208	0.27	
		239.81	208	0.13	
		237.22	197	0.17	
		239.81	197	0.18	
		230.75	176	0.24	
	4	226.87	163	0.28	0.26
		230.75	163	0.29	
		230.75	163	0.29	
		225.57	163	0.28	
		229.46	206	0.10	
		234.63	163	0.31	
	5	229.46	163	0.29	0.22
		219.1	163	0.26	

Water Type	Time (Minute)	TDS meter (ppm)	TDS Sensor (ppm)	Error (%)	Average Error (%)
		215.22	163	0.24	
		213.93	163	0.24	
		213.93	202	0.06	
		215.22	163	0.24	
Pond Water	1	2112.8	2057	0.03	0.04
		2115.5	2057	0.03	
		2118.1	2057	0.03	
		2112.8	2159	0.02	
		2112.8	2057	0.03	
		2114.2	2287	0.08	
	2	2112.8	2057	0.03	0.04
		2112.8	2057	0.03	
		2112.8	2057	0.03	
		2115.5	2176	0.03	
		2110.2	2278	0.08	
		2110.2	2175	0.03	
	3	2115.5	2225	0.05	0.04
		2114.2	2229	0.05	
		2115.5	2057	0.03	
		2114.2	2057	0.03	
		2114.2	2057	0.03	
		2110.2	2200	0.04	
	4	2112.8	2200	0.04	0.03
		2114.2	2200	0.04	
		2116.8	2057	0.03	
		2114.2	2057	0.03	
		2115.5	2057	0.03	
		2115.5	2057	0.03	
	5	2115.5	2057	0.03	0.03
		2112.8	2057	0.03	
		2116.8	2057	0.03	
		2114.2	2257	0.07	
		2115.5	2057	0.03	
		2112.8	2109	0.00	
	6	2143.6	2057	0.04	0.04
		2142.3	2007	0.06	
		2143.6	2057	0.04	
		2139.7	2057	0.04	
		2142.3	2057	0.04	
		2143.6	2057	0.04	
Average Total Error					0.10

The above results show the difference in the level of total dissolved solids between unbranded mineral water and pond water. In the table, an average error value of 0.10% has been calculated, which shows that the sensor has a very small error and good accuracy. This data is useful for further analysis and ensuring the quality of the measurements made by the TDS sensor.

System Testing Results

In the overall test, the sensor measurement results from this tool will be compared with the values obtained from TDS meters and Turbidity meters available in the market. This step is important to ensure that the sensor used in this tool has a level of accuracy comparable to standard measuring instruments that have been tested. In addition, this tool will also be tested to ensure its ability to determine the quality of clean water based on PPM parameters. This test will include various water samples with different levels of dissolved solids, to evaluate the consistency and reliability of the sensor in categorizing water as clean or dirty. Thus, this test will not only assess the accuracy of the device in measuring TDS but also the validity of the device in providing accurate and reliable water quality assessment. The results of this test will provide important data for further analysis and quality improvement of the measuring instrument.

TDS Sensor Testing with TDS Meter The purpose of this test is to determine the difference in measurement results between the device made and the TDS meter.

Table 2. System Testing Results

Types of Water	TDS Meter Standart	TDS Sensor
Unbranded mineral water	286	276
pond water	2114	2110
well water	176	174
PDAM water	125	120
Aqua water	102	100
Le mineral water	102	100
Water	88	85
Rice field water	1167	1158
Average	520	515.375
Average error	0.008894%	

The results of testing and calculations on eight samples showed that the average error value was 0.008894%. This indicates that the device has a high level of accuracy because the error in measurement is very small. These results indicate that the device can provide consistent and reliable results in measuring the level of dissolved solids in water.

Water Quality Testing

Clean water quality testing was conducted by carefully measuring 12 water samples, focusing on the parameter of total dissolved solids measured in PPM. The standard for clean water quality stipulates that the tested water must have a dissolved solids value of less than 500 PPM to be considered clean. If a water sample meets only one parameter requirement, then the water will be categorized as dirty water and considered unfit for human consumption. In this testing process, not only the total dissolved solids value is considered, but also the turbidity of the water as an additional indicator of its quality. The results of this test will provide important information to evaluate the safety and suitability of water for human consumption needs, as well as provide a basis for corrective measures or actions needed to maintain water quality suitable for use.

Table 3. Results of Water Quality Testing

Water Type	TDS Sensor	Water Quality
Unbranded mineral water	276	Clean Water
Aquades	25	Clean Water
well water	174	Clean Water
PDAM water	120	Clean Water
Aqua water	100	Clean Water
Le mineral water	100	Clean Water
Water	85	Clean Water
Rice field water 1	1003	Dirty Water
Rice Field Water 2	1158	Dirty Water
pond water	2110	Dirty Water
Catfish pond water 1	2167	Dirty Water
Catfish pond water 2	2786	Dirty Water

Here is a visualization at the serial monitor:

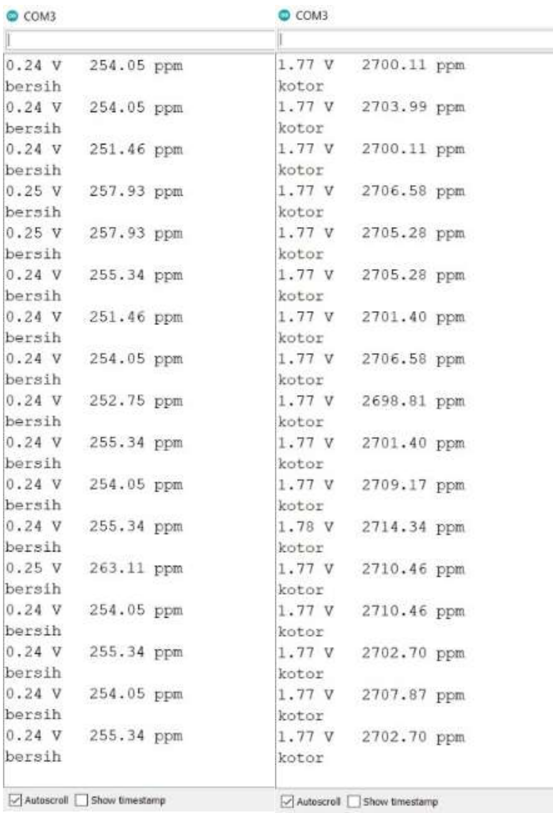

Figure 8. Serial Monitor Results

Figure 8 shows the reading results from the serial monitor, which contains data about the water quality based on the TDS (Total Dissolved Solids) value. In this experiment, water is categorized into two types of quality, namely clean and dirty. These categories help in quick analysis and decision making for water quality improvement measures using the ESP32-based monitoring system.

Table 3 illustrates the results of the water quality testing based on the number of dissolved solids measured in PPM units. Based on the information listed in the table, it can be concluded that out of a total of 12 water samples tested, 7 of them, including Unbranded mineral water, Aquades, well water, PDAM water, Aqua water, Le mineral water, and Water, have met the criteria as clean water with values < 500 PPM. Meanwhile, water from Rice field water 1, Rice field water 2, pond water, Catfish Pond water 1, and Catfish Pond water 2 were all categorized as dirty water.

CONCLUSION

The TDS (Total Dissolved Solids) sensor has been used successfully to measure the concentration of dissolved solids in water with a high level of accuracy (0.008894% in average error). The results of water quality testing also confirmed the ability of the TDS sensor to distinguish between clean water and dirty water based on the parameters of the amount of dissolved solids in the water. The ability of this sensor to provide real-time information about water quality has the potential to support more effective monitoring and management of the water environment.

Our findings pave the way for future research, which should focus on expanding the scope of the TDS sensor's application. This result could involve testing its reliability across a broader range of water types and diverse sampling locations, thereby assessing its performance in various environmental conditions. Furthermore, developing this sensor technology should be a priority, emphasising enhancing its sensitivity and resistance to the diverse environmental parameters that influence water quality.

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