Low-Cost Monitoring of Freshwater Quality on Board Vessels

Edi Kurniawan[1], Henna Nurdiansari[1], Diana Alia[1*], Doni Doni, Bagus Indra
[1]*Teknik Rekayasa Kelistrikan Kapal, Politeknik Pelayaran Surabaya, Surabaya, Indonesia*
* diana.alia@poltekpel-sby.ac.id

***Abstract*— Fresh water is an important thing in the ship, which is required by crews or passengers. Fresh water's quality hasn't met standards can disrupt the activities of the ship's crew. This research aims to build a monitoring water treatment system on a ship. In this research is equipped with a SEN0189 turbidity sensor, a SEN0244 TDS sensor, and a SEN0161 PH sensor to monitor freshwater quality. Water from the bunker flowed through the filter system and then continued to the tank. All sensors are placed in the tank to ensure that freshwater meets the standard. parameter standards of fresh water are detected by the PH sensor, Total Dissolved Solids (TDS) sensor, and turbidity sensor. The data appeared on an LCD monitor. If freshwater hasn't met standard quality, the buzzer and LED turn on. The results of water treatment testing using the ATMEGA 2560 show that the system can work optimally in treating fresh water. Margin error from the proposed method obtained 5,6% within fabrication costs about 1 million rupiahs.**

Keywords*— *Freshwater Quality, ATMEGA 2560; Turbidity Sensor SEN0189; TDS Sensor SEN0244; PH Sensor SEN0161

1. Introduction

The ship is designed to transport passengers or cargo across waters and is equipped with various facilities, including the essential supply of fresh water[1]. This freshwater is crucial for cooling the main engine and for the daily needs of the ship's crew, such as bathing, washing, and cooking. Fresh water is typically obtained from land or specialized ships, but some ships are equipped with fresh water generators and reverse osmosis systems to produce fresh water that is stored in tanks[2]. The quality of freshwater must meet certain standards[3], as If water cleanliness standards are not met, it can cause various health problems such as skin diseases and the risk of bacterial contamination[4]. As a result, freshwater quality on board is crucial.

Nowadays, technology has become modern technology in monitoring water quality[2], [5], [6][7]. In [6], estimated freshwater biodiversity in real-time using a Ph sensor, temperature sensor, and TDS sensor. In the study [7], freshwater monitoring was carried out using temperature sensors, pH sensors, and Dissolved Oxygen (DO) sensors. In the study[5], freshwater monitoring was carried out using temperature sensors, pH sensors, and turbidity sensors. from the study [5]–[7] the system sends standard freshwater parameter data wirelessly. where this is not relevant if applied to ships, because of the many obstacles that exist so that the attenuation and loss are large. This causes delays or lost data packets.

Based on the problem of the availability of clean water that meets the standards, this study created a cheap freshwater quality parameter monitoring tool. where in previous studies using wireless water monitoring. However, in applications on ships, wireless data transmission experiences many obstacles, so in this study data transmission is wired and equipped with data storage features via microSD. so that it can facilitate the ship's crew to carry out maintenance, repair equipment, and check the suitability of fresh water for daily needs. This research aims to achieve freshwater quality parameters that can be measured and monitored easily with a low-cost monitoring system. Also, the data could predict the condition of the fresh freshwater bunker tank on the ship. in the proposed method integrates a pH sensor, TDS sensor, and Turbidity sensor. and is equipped with an LCD and buzzer to display data monitoring in real-time. All data measured by the sensor is processed by ATMEGA 2560 as a microcontroller.

2. Literature

A. Water quality

According to [3], water quality parameters can be classified into three part:

A. Yulianto et al. (eds.), *Proceedings of the International Conference of Inland Water and Ferries Transport Polytechnic of Palembang on Technology and Environment (IWPOSPA-TE 2024)*, Advances in Engineering Research 274,
https://doi.org/10.2991/978-94-6463-841-7_11

1) Physical: turbidity, temperature, color, taste and odor, solids, electrical conductivity (EC)
2) Chemical: pH, acidity, alkalinity, chlorine residual, sulfate, nitrogen, fluoride, iron and manganese, copper and zinc, hardness, dissolved oxygen, Biochemical oxygen demand, chemical oxygen demand, toxic inorganic substances, toxic organic substances, radioactive substance
3) Biological: bacteria, algae, viruses, protozoa

B. Turbidity

Turbidity is a metric used to describe how cloudy or hazy a fluid (usually water) is because of suspended particles. These particles, which scatter and absorb light to give the appearance of murky water, can be silt, plankton, microbes, or contaminants. Because excessive turbidity can signal the presence of contaminants that could jeopardize the health and safety of aquatic habitats and drinking water supplies, turbidity is a crucial indicator in the monitoring of water quality. Typically, a turbidity meter is used to quantify it in nephelometric turbidity units (NTU). NTU is equal to one milligram per liter of suspended silica[3]. The average human can see turbidity of more than 5 NTU, but in murky water, turbidity can reach 100 NTU [].

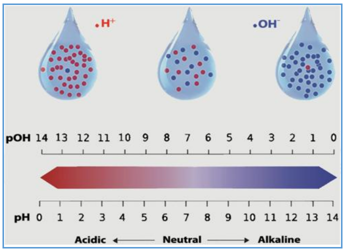
C. Total Dissolved Solids (TDS)

TDS is the total amount of dissolved materials in water. These materials may consist of trace amounts of dissolved organic matter in water as well as inorganic salts (such as calcium, magnesium, potassium, and sodium). TDS is commonly measured in parts per million (ppm) or milligrams per liter (mg/L). According to the TDS content per liter, water can be categorized as follows[3]:
• freshwater: <1500 mg/L TDS;
• brackish water: 1500–5000 mg/L TDS;
• saline water: >5000 mg/L TDS.

TDS concentrations are a common measure of water quality. Elevated total dissolved solids (TDS) may indicate the existence of undesirable or perhaps hazardous impurities, which might impact the flavor, hardness, and appropriateness of water for consumption or commercial applications. Not all TDS, though, is bad; some contain necessary minerals. A TDS meter is commonly used to detect TDS, and it calculates the concentration by utilizing the water's electrical conductivity.

D. pH

A pH scale is used for calculating how acidic or alkaline a solution is. The scale is logarithmic and has a range of 0 to 14, as shown in figure 1:
1) Pure water has a pH of 7, which is regarded as neutral.
2) Acidity is defined as a pH of less than 7, with 0 being the most acidic.
3) Alkalinity, or basicity, is indicated by a pH of more than 7, with 14 being the most alkaline.



a.

Fig. 1. pH of water

The concentration of hydrogen ions (H + H +) in a solution is measured using the pH scale. A tenfold difference in acidity or alkalinity is represented by each full number shift on the pH scale. A pH of 4 solution, for instance, is 10 times more acidic than a pH 5 solution.In many chemical, biological, and environmental processes, pH is an important parameter. For instance, pH has an impact on the toxicity and solubility of metals in water, as well as the well-being of aquatic life. pH indicator strips or pH meters are frequently used for measurement.

E. Electrical Conductivity (EC)

EC is a measure of expressing a material's electrical conductivity. The ability of water to conduct electricity is known as electrical conductivity in the context of water quality, and it is directly correlated with the amount of dissolved ions (such as salts, minerals, and other inorganic compounds) in the water. Either millisiemens per centimeter (mS/cm) or microsiemens per centimeter (µS/cm) are commonly used measurements for EC. A larger concentration of dissolved ions is indicated by a higher conductivity value.

Typical conductivity of water is as follows:

1) Ultra-pure water: $5.5 \times 10{-}6$ S/m;
2) Drinking water: 0.005–0.05 S/m;
3) Seawater: 5 S/m.

The electrical conductivity can be used to estimate the TDS value of water as follows[3]:

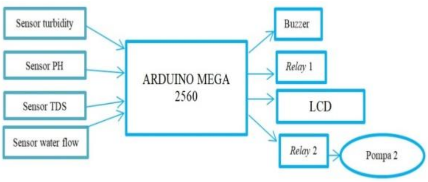
$$TDS\ (mg / L) \cong EC\ (dS / m\ or\ umho / cm) \times (0.64) \qquad (1)$$

EC indicates that there may be contamination from sources such as industrial waste, wastewater discharge, or agricultural runoff if there is a high concentration of dissolved salts and ions. shows little ions dissolved in water, which is often found in pure or distilled water. Aquatic ecosystems are monitored and their health is evaluated using EC. Conductivity variations may indicate changes in the quality of the water, such as the arrival of contaminants. The degree of conductivity in water can be used to assess whether it is safe to consume. Elevated conductivity may suggest the existence of contaminants that could impact flavor, well-being, or water treatment procedures.

3. Research Method

In this paper, several devices were used and assembled carefully to form an architecture depicted in Figure (2). To highlight the distinctiveness of the suggested system, the architecture incorporates both a general hardware architecture utilizing the Arduino Mega 2560. Four different types of sensors were employed to support the three water quality monitoring metrics that the system is designed to record: Turbidity, TDS, EC, pH, and also water flow. Moreover, additional devices served as media for wire data transfer to an LCD, micro SD, and Buzzer.

Data from these sensors are processed by the microcontroller to control relays functioning as pump switches and to send data to an LCD for display and a micro SD to save data. These sensors detect the quality of fresh water after the water treatment process; if it met quality standards, the water is distributed, otherwise, it is pumped back to the storage tank for further processing.



b.

Fig. 2. Block diagram of proposed method

Furthermore, to protect from damage from high water pressure or blockages in the system, the system has a safety mechanism that automatically turns off the pump if the water flow is less than 500 milliliters per minute.

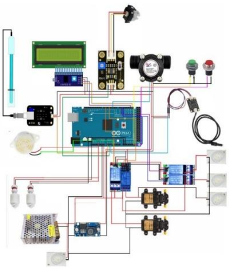


Fig. 3. Hardware architecture

Figure 3 illustrates how sensors are submerged inside a water container. The sensors may be located in one or more containers at various locations. Every container has a relay node installed, which is where the sensors read and gather the measurement data. Subsequently, the data is saved on the Micro SD card and shown in real-time on the LCD.

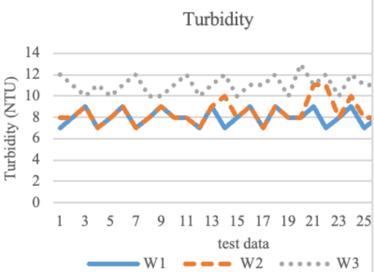
4. RESULT

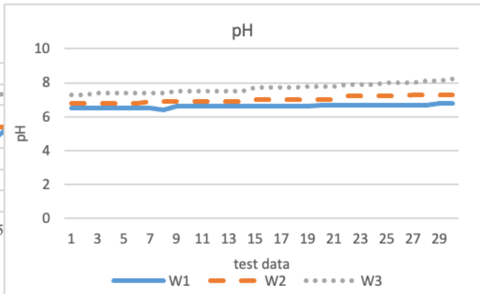
The devices that the proposed system makes use of to facilitate network node communication are listed in Table I. All the devices used can be purchased on the market at a low price.

TABLE I. TABLE TYPE STYLES

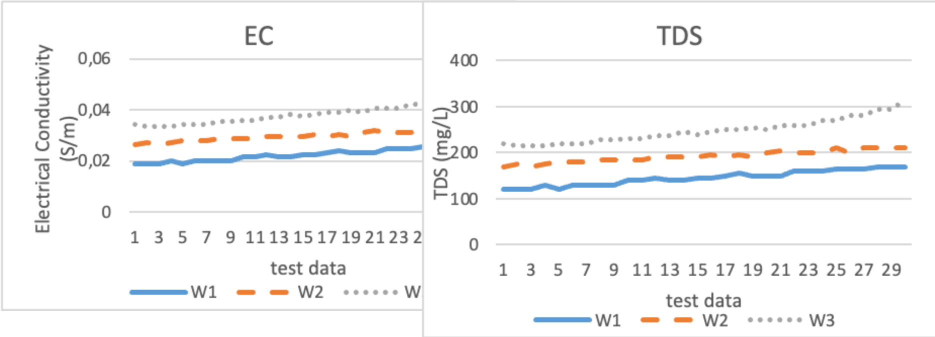
Metric	*Sensor name*	*Unit*	*Price*
pH	SEN0161		IDR447.140
TDS	SEN0244	mg/L	IDR119.000
Turbidity	SEN0189	NTU	IDR205.000
EC	SEN0244	S/m	-
Flow meter	YF-S201		IDR25.500
microcontroller	Arduino Mega 2560		IDR176.000
		Total	IDR972.640

The experiment was undertaken for ninety days to monitor the water quality. The water is placed in tanks for ninety days. The data is pulled every thirty days so that there is data for the first thirty days (W1), data for the second thirty days (W2), and data for the third thirty days (W3). The tank used is a steel tank without any paint coating, so the water can be contaminated with rust. This is simulated as closely as possible to the conditions of a freshwater bunker on a ship. Every day, thirty minutes were used to sample the data. The sensors were submerged in water within an aquarium situated within a room with a typical ambient temperature of approximately 20 to 25 degrees Celsius. By powering the devices, the measurement assessment can be started immediately after the sensors have been submerged in water.





(a) (b)



(c) (d)

Fig. 4. Data of (a) Turbidity (b) pH (c) EC (d) TDS from water in the bunker

Figure 4 (a) shows turbidity data for 90 days without water replacement. In the last 30 days, the turbidity value was more than 5 NTU. Where a large enough value can indicate that the water is cloudy and there are particles in the water that can be seen by the human eye. Whereas, in Table II shown the comparative values between laboratory test results and the turbidity values detected by the system.

TABLE II. TURBIDITY DATA SAMPLING EVERY 30 DAYS

Sampling condition	model	lab	error
W1	8	8	0
W2	8	7	1
W3	11	11	0

The pH measurement in the freshwater bunker is shown in Figure 4 (b). Where the pH value continues to rise from a range of 6.5 to 8. This is possible because the water has been contaminated by the rusty bunker. Table III shows a comparison of measurement results with the proposed system with laboratory test results with the same water sample and the same time. In the third test, a difference of 0.01 was obtained between the measurement results of the tool and the laboratory.

TABLE III. PH DATA SAMPLING EVERY 30 DAYS

Sampling condition	model	lab	error
W1	6,8	6,8	0
W2	7,3	7,3	0
W3	8,2	8,3	-0,1

EC is a material's electrical conductivity contained in water. The EC value is directly proportional to the TDS value. This is proven by the similarity of the trends in the graphs in Figure 4 (c) and Figure 4 (d). Where from day to day the TDS and EC values increase. This is caused by the water in the bunker becoming increasingly turbid due to rust contamination and the presence of microorganisms that grow. This is confirmed by the results of turbidity measurements in Figure 4.

TABLE IV. EC DATA SAMPLING EVERY 30 DAYS

Sampling condition	Model (S/m)	Lab (S/m)	error
W1	0,02031	0,02578	-0,0054
W2	0,02968	0,03359	-0,0039
W3	0,0343	0,04968	-0,0023

From the data collected within ninety days, it can be concluded that the margin of error obtained is 5.6%. The calculation of the margin of error (E) is calculated using the formula below.

$$E = \frac{(1.96 \times \sigma)}{\sqrt{N}}. \quad (2)$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}, \quad (3)$$

Where standard deviation (σ), N is the number of days and x_i is the i-th data.

TABLE V. TDS DATA SAMPLING EVERY 30 DAYS

Sampling condition	model	lab	error
W1	170	175	-5
W2	210	215	-5
W3	315	318	-3

From the overall test results of the proposed method, it was concluded that on the 86th day the water pH had exceeded the specified threshold of 8, this was supported by the Turbidity value reaching 14, and TDS reaching 280 NTU or equivalent to EC approaching 0.05S/m. In the last 4 days, the alarm sounded indicating that the water did not meet clean water standards.

5. CONCLUSION

In this study, the standard parameters of freshwater quality can be monitored in real-time which is displayed on the LCD and the data can also be stored in a microSD. From the test results it can be concluded that the device can work well for ninety days with a margin of error of 5.6%. Then, water stored for a long time in a bunker made of iron can increase pH, Turbidity, TSD, and also EC values significantly so that on the eighty-sixth day, the buzzer lights up indicating that the water is no longer suitable for use. therefore, in order to meet the standards of freshwater quality on board, it is necessary to replace fresh water in the bunker every week.

REFERENCES

[1] S. H. Lafta and E. A. Albahrani, “Fabrication of a Simple Computerized High Power Supply for Magnetic Measurements,” *Int. J. Electr. Eng. Comput. Sci.*, vol. 6, no. April, pp. 76–85, 2024, doi: 10.37394/232027.2024.6.8.

[2] F. N. Zohedi, M. S. M. Aras, H. Anuarkasdirin, M. B. Bahar, and L. Abdullah, “System Identification (Si) Modelling, Controller Design and Hardware Testing for Vertical Trajectory of Underwater Remotely Operated Vehicle (Rov),” *IIUM Eng. J.*, vol. 24, no. 2, pp. 131–140, 2023, doi: 10.31436/iiumej.v24i2.2759.

[3] C. A. Buckner *et al.*, “We are IntechOpen , the world ’ s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %,” *Intech*, vol. 11, no. tourism, p. 13, 2016, [Online]. Available: https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics.

[4] A. Amyati, “Kualitas Fisik dan Kimia Air Bersih di Pasar Beringharjo Yogyakarta,” *J. Ilmu Kesehat. Masy.*, vol. 11, no. 03, pp. 270–278, 2022, doi: 10.33221/jikm.v11i03.1227.

[5] Y. Wang, I. W. H. Ho, Y. Chen, Y. Wang, and Y. Lin, “Real-Time Water Quality Monitoring and Estimation in AIoT for Freshwater Biodiversity Conservation,” *IEEE Internet Things J.*, vol. 9, no. 16, pp. 14366–14374, 2022, doi: 10.1109/JIOT.2021.3078166.

[6] M. S. U. Chowdury *et al.*, “IoT based real-time river water quality monitoring system,” *Procedia Comput. Sci.*, vol. 155, pp. 161–168, 2019, doi: 10.1016/j.procs.2019.08.025.

[7] A. A. Pranata, J. M. Lee, and D. S. Kim, “Towards an IoT-based water quality monitoring system with brokerless pub/sub architecture,” *IEEE Work. Local Metrop. Area Networks*, vol. 2017-June, 2017, doi: 10.1109/LANMAN.2017.7972166.