The Influence of the Tide Levels on the Water Electrical Conductivity Parameter in the Estuary Area: In-Site and Real-Time Measurement

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Abstract *- One area that requires attention in water quality studies is the estuarine ecosystem. Estuaries are transition zones connecting freshwater and marine waters, thus possessing unique environmental dynamics. However, there is limited information regarding the effect of sea tides in the area on local estuary water quality. Therefore, this study aims to identify the existing relationship between sea tide levels and EC values, using an IoT-based system that is portable, lightweight, and capable of operating in real time. This study was conducted over five days in Senggigi village, Batulayar, West Nusa Tenggara, Indonesia. The collected data focused on the EC parameter's water quality levels at different tide levels, which were monitored using the self-developed system. This system was developed using an EC sensor, a microcontroller, and a wireless internet router (for wireless data communication via ThingSpeak.com). This system was also equipped with a pH sensor, a TDS sensor, and a water temperature sensor. The recorded data show that the resulting data are valid and highly accurate, and that the system is ready for examination at the measurement area. The resulting data show that the correlation between tide level and EC value is logarithmic, with a regression coefficient of 0.934. The EC level was about 20.42 – 62.54 mS/cm, depending on the tide level. It can be concluded that the tide level indeed influences the EC parameter in the estuary area. Moreover, TDS plays an important role in regulating EC levels, underscoring the need to systematically measure this parameter in any estuarine water-quality study.*

Keywords: *Electrical Conductivity; Estuary; Tide Level; Water Quality*

INTRODUCTION

Water is an essential component that supports the survival of all life on Earth. The availability of water that meets quality standards is crucial for ecosystem stability, public health, and the sustainability of various social and economic activities (Mørk et al., 2016). Therefore, studying water quality conditions across various regions is a crucial aspect of natural resource and environmental management (Luo et al., 2024).

One area that requires attention in water quality studies is the estuarine ecosystem (Gorito et al., 2024). Estuaries are transition zones connecting freshwater and marine waters, and thus possess unique environmental dynamics (Miguel et al., 2019). This area serves as a habitat for various organisms, a migration route for aquatic biota, and a site for interacting physical, chemical, and biological processes. The complexity of these processes makes estuaries dynamic ecosystems and highly sensitive to environmental changes, both natural and those influenced by human activities (Dix et al., 2025).

Due to their strategic location at the confluence of rivers and the sea, estuaries are highly vulnerable to pollution and changes in physical (Jiang et al., 2024). The influx of domestic waste, residential runoff, changes in upstream land use, and increased tourism activity in coastal areas can disrupt the stability of water quality parameters. Furthermore, seawater intrusion, a consequence of climate change, also affects the salinity, dissolved ion content, and electrical properties of estuarine water (Zhu et al., 2025). These conditions emphasize the importance of regular water quality monitoring to accurately identify changes (Xu et al., 2025).

In line with this urgency, several previous studies have attempted to assess estuarine water quality through physical-chemical parameter measurements. Total Dissolved Solids (TDS) and Electrical Conductivity (EC) values can reflect the level of mineralization and salinity influenced by anthropogenic activities (Aslam et al., 2017). Fluctuations in pH and electrical conductivity serve as early indicators of changes in water quality due to tidal dynamics and seawater intrusion (Khan et al., 2023). Estuarine areas adjacent to tourist areas require more intensive monitoring due to their vulnerability to ecological pressures. However, studies on water quality in the Kerandangan Estuary remain very limited, underscoring the need for further research to provide comprehensive scientific data.

EC monitoring can be specifically conducted using two methods: direct and indirect measurements (Benavente et al., 2025; Guo et al., 2025). Direct measurements can be conducted either individually or continuously using an integrated system in the relevant field. On the other hand, indirect measurements require larger equipment and cannot be conducted on-site. A direct water-quality assessment using an IoT (Internet of Things)-based system is costly, as it requires multiple platforms (Azreen et al., 2024). Directly measuring estuarine water quality requires slightly different techniques, given that EC levels in estuaries and freshwater ecosystems differ.

Lombok island, West Nusa Tenggara, Indonesia, features numerous estuaries and significant mangrove ecosystems, such as in East Lombok (Gili Lawang, Gili Sulat, Sambelia) and West Lombok (Cemare River, Rasu Bay, Sepi Bay). These estuaries are crucial for biodiversity like crabs and fish, though facing threats from conversion. In essence, Lombok's extensive coastlines, especially in the east and west, are characterized by these productive estuarine and mangrove zones, making them important ecological zones to protect.

One of the estuary areas in West Lombok Regency is the area around Senggigi, such as Kerandangan estuary. This area has several estuaries, both directly and indirectly connected to the coastline. This area is known as a favorite tourist destination on the island of Lombok. Therefore, information on estuary water quality can help improve local tourism, given the many supporting tourism facilities around the estuary. On the other hand, there has been little direct assessment of estuary water quality. Furthermore, there is limited information regarding the effect of sea tides in the area on local estuary water quality. Therefore, this study aims to identify the existing relationship between sea tide levels and EC values, using an IoT-based system that is portable, lightweight, and capable of operating in real time.

RESEARCH METHODS

a. Time and Location

This study was conducted over five days in Kerandangan estuary, Senggigi village, Batulayar, West Lombok Regency, West Nusa Tenggara, Indonesia (-8.4890002; 116.0394387, altitude is ±3 mdpl). The collected data focused on the EC parameter's water quality levels at different tide levels (in units of meters). The water quality levels were obtained from direct multiple measurements using our self-developed system from 10-14 November 2025.

b. System Development

The system was developed using an EC sensor (DFRobot Gravity K-1 version, 0-20 mS/cm) and other supporting sensors. This device is a self-developed system named Kit PEKAT 02. All sensors were connected to a microcontroller and a wireless internet router (Figure 1). The system was placed on the surface of the estuary water (floating) during the measurement. This system was turned on for five days to monitor the level of ECs using a wireless data communication (via ThingSpeak.com) (Budianto et al., 2023; Wardoyo et al., 2022; Yani et al., 2024). This system was also equipped with a microcontroller, a pH sensor, a TDS sensor, and a water temperature sensor. The system has been calibrated using a standard device.

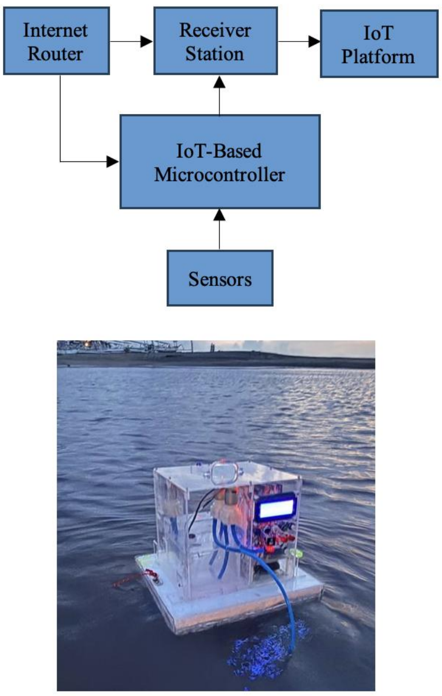

Figure 1. The Schematic of the Self-Developed Measurement System

c. Statistical Analysis

The resulting data were plotted as a graph showing the correlation between tide levels and the EC parameter as a function of water quality level. All data were interpreted as the mean value and the SD (standard deviation), while the significance level was obtained using a Student's *t*-test (Yani et al., 2024).

RESULTS AND DISCUSSION

Results

a. System Calibration

The system's calibration data are presented in Table 1. It can be seen that the system has a response time of < 2s (average), with an accuracy of ~95%. These values are obtained from comparisons between the standard and the developed systems. These processes were conducted at 25-26 °C. For the EC parameter, the calibration data range from the lowest (0 μS/cm) to the highest (8000 μS/cm), with a regression coefficient (R^2) of >0.98 (Figure 2). The linearity is above 98%, with a response time of < 60s.

Table 1. The Calibration Data of the System

Parameters	Results	
	Accuracy (%)	Response Time (s)
EC (mS/cm)	95	1.56
pH	94	1.97
TDS (ppm)	95	1.01
Temperature (°C)	95	1.04

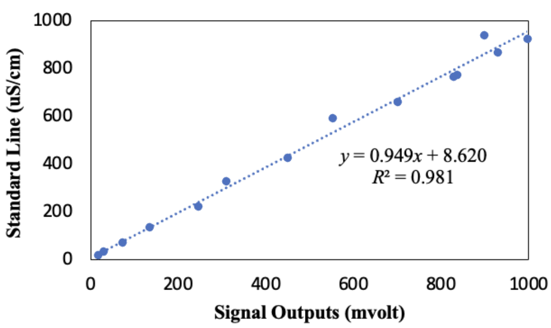

Figure 2. The EC Calibration Data

The obtained regression function, *y* (a linear approximation of the EC value), was then implemented in the microcontroller's program code (x = sensor's output). The calibration function (y) ensures that the resulting data are valid and highly accurate, and the system is ready for examination at the measurement area ($y = a.x + b$).

b. Direct Measurement

The calibrated system was used to measure and monitor the EC parameter (along with other supporting parameters) in the sampling area (Senggigi village). These measurements were conducted for five consecutive days.

Table 2. The Recorded Tide Levels at the Sampling Area

Measurement Day	Tide Level (m)	
	High	Low
Day 1	1.96	1.05
Day 2	1.80	0.43
Day 3	1.62	0.55
Day 4	1.43	0.64
Day 5	1.43	0.72

Table 3. The Measured EC Levels at the Sampling Area

Measurement Day	Tide Level (mS/cm)	
	High	Low
Day 1	62.54	57.31
Day 2	60.46	21.78
Day 3	58.04	29.77
Day 4	57.21	34.30
Day 5	57.64	31.25

Table 2 shows the tide levels at certain sampling periods. Meanwhile, Table 3 interprets the EC levels among all measurement periods. It can be confirmed that each measurement day had a different tide level. The highest tide level belongs to Day 1. At this time, the tide level is about 1.96 m, resulting in a high EC (62.54 mS/cm). The second position belongs to Day 2, with the value of 1.80 m and 60.46 mS/cm. These data indicate a correlation between tide level and the EC parameter (Jantama et al., 2025).

It can be seen further that at Day 4, the EC value is about 57.21 mS/cm, while the tide level is 1.43 m. The resulting data indicate a strong correlation between tide level and EC value in the estuary, with higher tide levels associated with higher EC values. Based on this assumption, this study aims to analyse the possible correlation (Figure 3).

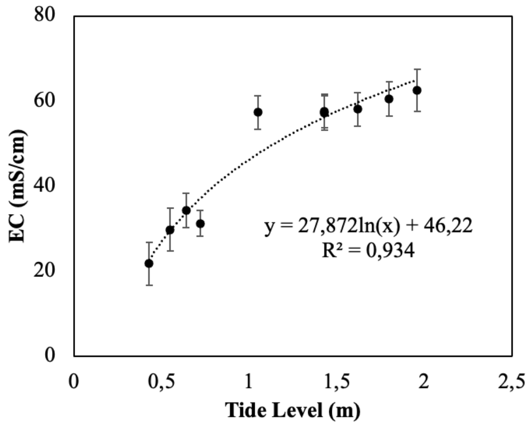

Figure 3. The correlation between tide level and EC

Figure 3 interprets the correlation between tide level and EC value. It can be seen that there is a logarithmic correlation with a regression value of 0.934:

$$y = 27.9\ln(x) + 46.2 \quad (1)$$

As shown in the equation above, y represents the EC value, while x represents the tide level.

Discussion

In the context of coastal ecosystem management, the availability of accurate water-quality data is a crucial foundation for science-based policy formulation. This data is used to assess the sustainability of estuary ecological functions, monitor the impacts of anthropogenic activities, and support environmental conservation efforts. Therefore, research focused on estuarine water quality monitoring is highly urgent, particularly in coastal areas experiencing social, economic, and tourism development.

Based on this background, this research focuses on water quality monitoring, taking the study location at Muara Kerandangan. This area has unique ecological characteristics and has experienced increased human activity in recent years. The complex interactions between community activities, hydrological dynamics, and environmental conditions make Muara Kerandangan an important location for scientific study. Through systematic measurements of physical and chemical parameters, this research is expected to provide an actual picture of the estuary's water quality and serve as a basis for sustainable coastal environmental management and protection efforts.

The level of EC in estuaries is highly dependent on tidal levels due to the exchange of water masses between the sea and rivers. At high tide, seawater flows further upstream (in the estuary), bringing with it a large number of ions that increase the water's ability to conduct electricity. As a result, the EC value increases significantly.

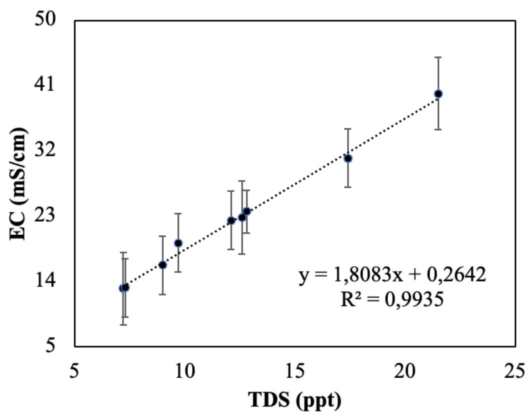

Figure 4. The correlation between TDS and EC

In addition to EC, TDS also plays a significant role in determining estuarine water quality. An increase in TDS indicates a higher concentration of dissolved substances, including minerals, organic matter, and anthropogenic contaminants ($y = 1.8083x + 0.2642$) (Figure 4). According to a previous study, high TDS values in estuarine areas are often associated with seawater intrusion, domestic waste discharge, and surface runoff from residential activities. This research confirms that TDS is a key parameter for assessing water quality stability, particularly in coastal areas under increasingly intense environmental pressures. The relationship between TDS and EC underscores the importance of systematically measuring this parameter in any estuarine water-quality study.

CONCLUSION

It can be concluded that the resulting data are valid and highly accurate, and that the system is ready for examination at the measurement area. The resulting data show that the correlation between tide level and EC value is logarithmic, with a regression coefficient of 0.934. It can be concluded that the tide level indeed influences the EC parameter in the estuary area. Moreover, TDS plays an important role in regulating EC levels, underscoring the need to systematically measure this parameter in any estuarine water-quality study.

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